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FINAL REPORT

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The primary purpose of this report was to investigate flight simulator commonality. Visual system commonality was investigated using an advanced development program called the Visual System Component Development Program (VSCDP) as a baseline. In addition, the study investigated commonality issues of such subsystems as motion platforms, instructional features, computer hardware and software, student stations, etc.

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PM TRADE
U.S. ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND
DARCOM

SYNTHETIC FLIGHT TRAINING SYSTEM STUDY

FINAL REPORT

Prepared for:

The Project Manager for Training Devices
Aviation Systems Division

23 December 1983

Prepared by:

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF ACRONYMS

Ada JUG	-	Ada JOVIAL User's Group
Ada TEC	-	Ada Technical Committee
AH	-	Attack Helicopter
APSE	-	Ada Programming Support Environment
ATACDIG	-	Army Tactical Digital Image Generator
AOI	-	Area of Interest
AQC	-	Aircraft Qualification Course
BG	-	Background
BOD	-	Building Occupancy Date
C/A	-	Contract Award
CH	-	Cargo Helicopter
CGI	-	Computer Generated Imagery
CGSI	-	Computer Generated Synthesized Image
CMB	-	Camera Model Board
CMS	-	Combat Mission Simulator
CPG	-	Copilot Gunner
CRT	-	Cathode Ray Tube
CWEPT	-	Cockpit Weapons and Emergency Procedures Trainer
DIG	-	Digital Image Generator
DIGI	-	Digital Image Generator First Generation
DIGII	-	Digital Image Generator Second Generation
DTV	-	Daylight Television
DVO	-	Direct View Optics
ECM	-	Electronic Countermeasures
FLIR	-	Forward Looking Infrared
FOV	-	Field of View
FWS	-	Flight and Weapons Simulator
HDD	-	Head Down Display
HOD	-	Head Out Display
HOL	-	High Order Language
IHADSS	-	Integrated Helmet and Display Sight System
IFE	-	Instrument Flight Examiners

INS	-	Inertial Navigation System
IP	-	Instructor Pilot
IPC	-	Instructor Pilot Course
LHX	-	Light Helicopter
LSIG	-	Laser Scanning Image Generator
MOI	-	Methods of Instruction
MSI	-	Medium Scale Integration
NSN	-	National Stock Number
NVG	-	Night Vision Goggle
NOE	-	Nap-of-Earth
O&S	-	Operating and Support
OH	-	Observation Helicopter
ORT	-	Optical Relay Tube
OUSDRE	-	Office of the Undersecretary of Defense for Research and Engineering
PDL	-	Program Design Language
P^3I	-	Preplanned Product Improvement
PNVS	-	Pilot Night Vision System
PSE	-	Programming Support Environment
RAM	-	Random Access Memory
RFP	-	Request for Proposal
RFT	-	Ready for Training
SATT	-	Scout Attack Team Trainer
SCAT	-	Scout and Attack
SFTS	-	Synthetic Flight Training System
SIP	-	Standardization Instructor Pilot
SOW	-	Statement of Work
SSI	-	Small Scale Integration
STG	-	Synthetic Terrain Generator
TADS	-	Target Acquisition and Designation Sight
TDR	-	Training Device Requirement
TSTT	-	TADS Selected Task Trainer
TSU	-	Telescope Sight Unit
TTL	-	Transitor-Transitor Logic
UH	-	Utility Helicopter

USAAVNC	-	United States Army Aviation Center
VDU	-	Visual Display Unit
VSC	-	Visual System Component
VSCDP	-	Visual System Component Development Program
WAC	-	Wide Angle Collimated
WST	-	Weapon Systems Trainer

SYNTHETIC FLIGHT TRAINING SYSTEM STUDY

1.0 INTRODUCTION

1.1 BACKGROUND

The Project Manager for Training Devices (PM TRADE) is planning the acquisition and integration of advanced visual simulation technology for the Army's family of Synthetic Flight Training Systems (SFTS).

In 1967, Headquarters, USA Combat Development Command issued the first in a series of what are now entitled Training Device Requirements (TDR) documents for the development of the SFTS.

A significant portion of Section I - Statement of Requirement, of the current TDR dictates provision for:

> "the flexibility required for the modification of training programs and synthetic training equipment to reflect changes in training device technology, in the Army aviation mission, and in the equipment available to accomplish that mission."

The myriad of changes in training device technology and equipment have affected virtually every major functional area: Computation, instruction, motion platforms, etc. One functional area which has received considerable examination and analysis is visual simulation technology. According to the Statement of Work (SOW) in NAVTRAEQUIPCEN solicitation N61339-82-R-0139 for Visual System Component Development Program (VSCDP) Phase II - Hardware Development and Evaluation:

> "The need to advance visual simulation technology is driven by the fielding of increasingly sophisticated weapon systems for use in land based battles. The expanded operational capabilities and increasing operational costs for new weapon systems require increased usage of simulated environments for training up to full tactical mission capabilities. This program (VSCDP) has been established to accelerate the integration and system demonstration of next generation nap-of-the-earth (NOE) combat visual simulation technology."

The statement of need articulated above conveys the underlying rationale for the acquisition and integration of advanced visual simulation technology. The gravity of this need has been anticipated as witnessed by its designation as a Pre-Planned Product Improvement (P^3I) program to be integrated into the AH-64 Combat Mission Simulator (CMS), Device 2B40. The Army's requirement to acquire such technology in a prudent, cost effective manner within the constraints of an accelerated schedule contributed to the PM TRADE's decision to engage Science Applications, Incorporated and its subcontractors, Seville Training Systems and Mr. Benjamin Harrison, Consultant (hereafter referred to as the team) to conduct this study for the purposes detailed below in paragraph 1.2.

1.2 PURPOSE

The primary purposes of the SFTS study are to provide a basis for sound acquisition decisions concerning the integration of the Visual System Component Development Program (VSCDP) technology with the SFTS, and to identify opportunities for achieving instructional features, hardware and software commonality during the anticipated expansion and upgrading of the various SFTS simulators.

1.3 SCOPE

This study portrays the expected growth pattern of the SFTS and identifies various acquisition options available to decision makers who are charged with the accomplishment of the SFTS's growth. The scope of the study is limited to a time frame which takes into account the VSCDP's planned development schedule. In consideration thereof, the study focuses on near term (not more than 10 years) acquisition decisions. It is within this fundamental parameter that the study's basic issues of visual technology application and commonality are analyzed.

The study focuses on approximately five prinicpal organizations currently involved in advancing the state-of-the-art in visual technology. The data collected and analyzed from these organizations and other sources within the SFTS community were utilized to identify trade-offs between performance, cost, supportability and risk. These analyses provide the relevant decision makers with guidelines for the evaluation of the identified trade-offs in the time phase of each expected acquisition action.

1.4 ORGANIZATION OF THE REPORT

The report has five sections, including the present one. Section 2.0, Executive Summary, provides the essential information of the report, highlighting conclusions and recommendations. Section 3.0, Visual Technology Application, discusses the methodology applied by the team in the analysis of visual technology application. This section presents separate yet interrelated analyses on: Visual system acquisition actions anticipated over the next five to ten years; an assessment of the impact of VSCDP technology on enhancing system performance for each type SFTS; a cost and risk analysis and a comparison of visual acquisition alternatives based on the advantages and disadvantages derived from the above referenced analyses. Section 4.0, Commonality: Instructional Features, Hardware and Software, contains the documentation of the analysis on commonality. Section 5.0, Recommendations, specifies the recommended actions for visual system acquisition. It includes both acquisition actions and the necessary steps to further define areas that are still unknown at the time of the study. It also specifies the recommendations resulting from the commonality analysis (i.e., Section 4.0).

There are five appendices to the report. Appendix A provides a description of the SFTS program and its respective training devices. Appendix B describes the VSCDP and provides non-proprietary data regarding current visual technology developments. Appendix C identifies the current training requirements established for the SFTS. It documents information acquired from the user community which serves to indicate future implications for training. Appendix D provides the detailed analysis of the SFTS instructional features which were used for conducting the instructional features commonality analysis. Appendix E provides the detailed analysis of the AH-64 CMS software modules which were used as a baseline for conducting a portion of the software commonality analysis.

2.0 EXECUTIVE SUMMARY

2.1 BACKGROUND

On 20 May 1983, PM TRADE issued a task order for conduct of the Combat Mission Simulator (CMS) and Synthetic Flight Training System (SFTS) Study. The concept and scope of this study focus on the need for providing sound acquisition decisions concerning the integration of the Visual System Component Development Program (VSCDP) with the CMS, and to identify opportunities for achieving instructional features, hardware and software commonality during the anticipated expansion and upgrading of the various devices or trainers of the SFTS.

2.2 APPROACH

Due to the special significance of visual systems to aircraft simulators, the approach to the study encompassed two distinct issues. Section 3.0, Visual Technology Application, concentrates on advanced visual technology and addresses specific acquisition actions relating to visual system upgrade or purchase. Section 4.0, Commonality: Instructional Features, Hardware and Software, is a total system examination of the SFTS's devices, with particular attention directed to the issues of commonality and modularity.

2.3 ANALYSIS

Analysis addressed the two major subjects of this report: Visual Technology Application and System Commonality.

2.3.1 Visual System Component Development Program

The analysis of the VSCDP was divided into five separate yet interrelated categories: (1) Risk, (2) Training effectiveness, (3) Visual systems, (4) Cost, and (5) Acquisition decisions. The major findings of each category are summarized below.

a. Risk - A risk analysis was conducted to assess the risks associated with achieving the technical objectives within the planned VSCDP development schedule. The principal factor mitigating risk in the VSCDP is that five leading visual technology companies in addition to the two under contract are interested in matching the VSCDP performance requirements. The industry appears to acknowledge that a VSC-like capability will be a requirement to remain competitive within the market for military aircraft simulator visual systems. It is a conclusion of this study that at the present

time there is only a low risk that a VSC-like capability will be available at the time (October 1985) identified in the VSCDP schedule. However, certain VSC features will remain high risk until they are demonstrated. In particular, the combination of head/eye tracking with an area of interest display faces a technical and user acceptance risk that will be medium to high until the capability is actually demonstrated.

b. Training effectiveness - Based on the assumption that all technical objectives will be achieved, an assessment of the potential training effectiveness of the developed VSC and other SFTS visual systems was conducted by rating the potential utility of each visual system with respect to the visual cues required to perform 49 representative helicopter crew tasks. A principal question regarding visual technology in the present study is: Will the potential training effectiveness of VSCDP technology be sufficiently superior compared to the training effectiveness of the ATACDIG being developed for the AH-64 CMS to justify the cost and other impacts of replacing the ATACDIG with VSCDP technology? This same question also applies to Camera Model Board (CMB)/Laser Scanning Image Generator (LSIG) and Digital Image Generation I (DIG I).

The analysis conducted in Section 3.3, VSCDP Training Impact, provides an indication of the relative training effectiveness of the four visual systems (i.e., CMB/LSIG, DIG I, ATACDIG and VSCDP).

The DIG I system on the UH-60 FS has been rated as having limited training value. Nevertheless, with mediation (i.e., in a carefully designed and administered training program that attends specifically to the mediational processes employed), some effective visual task training can be and, in fact, is being conducted in it.

It should be noted that the overall rating of the DIG I would probably have been lower if the firing position tasks had been included in its assessment. The DIG I is relatively less useful for visual tasks that involve operation close to objects and surfaces or that require discrimination of image detail or range estimation.

The ATACDIG visual system was rated as having higher training value than the DIG I system because of its greater edge capacity and capability for increased detail. This capability for increased detail is particularly important in tasks that involve firing position operations (e.g., detection of small shifts in position relative to trees and terrain, target detection, and damage assessment). Even there, however, the

training value of the ATACDIG suffers from lack of ability to present object detail, but the limitation is not as severe as with the DIG I.

Although their overall ratings are similar, the CMB/LSIG and VSCDP visual applications differ with respect to their effectiveness for training specific tasks. Tasks involving distance and object identification tend to have an advantage with the CMB/LSIG, whereas tasks that require discrimination of fine detail favor the VSCDP. The reasons for these differences are that more visual information is inherently possible using the CMB/LSIG technology, since it involves video images of a model board that by its nature must be complete and continuous. By contrast, there is a limit to the amount of visual information that can be deployed in any affordable computer-generated system, although creative distribution of scene content (information) can lessen the impact of that limit. Offsetting this advantage of the CMB/LSIG, however, is the fact that much sharper images can be presented employing the VSCDP technology, thereby making fine discrimination possible during performance of some visual tasks. The slightly higher mean rating given the VSCDP for firing position tasks requiring discrimination of fine detail reflects this difference. The fact that CMB/LSIG technology has limited flexibility to depict changing scene content, such as is required to depict a rotor disc, weapons effects, and target damage, is also reflected in the ratings of tasks where such dynamics are needed for effective training without resorting to mediation.

c. Visual systems - There are three limitations inherent to CMB/LSIG technology that are not expected to be resolved by future technological advances. First, CMB/LSIG visual systems are mechanical devices that require extreme precision to operate effectively. Consequently, CMB/LSIG technology is subject to an additional maintenance burden not present in solid state Computer Generated Imagery (CGI). Second, model boards are physically large devices that place limits on the geographical area that can be represented. Presently, they are produced by hand. Any reduction in the size of objects without loss of detail is only feasible by some automated means of production, and by reducing the size of the probe. A scale limit is imposed by the ratio of the probe dimension to the helicopter dimension. If this limit is exceeded, the probe and probe protection system will not allow simulated helicopter flight or taxiing within realistic distances from terrain objects and surfaces. CGI, on the other hand, uses a disk-pack for the physical storage of the data base. Once the CGI data base is developed, multiple copies are easily stored and reproduced. This CGI capability provides the added benefit of allowing a given training device to choose among multiple terrain areas and seasonal conditions. Flexibility of this sort is

not anticipated for CMB/LSIG technology. Third, CMB/LSIG technology uses static models. Introduction of moving objects (e.g., targets or weapon effects), requires the integration of CGI with the model board. Achieving this capability in a realistic manner without imposing severe restraints on training scenarios requires a technical sophistication that approaches the full-up CGI itself. It is possible that some type of hybrid form of CMB/LSIG and CGI could produce systems that obviate these problems. CMB/LSIG technology, by itself, will not.

The primary limitation of CGI technology is that any element of information that is to be present in the output requires finite processing resources to be produced. CGI technology will (with the developed VSC) combine processing techniques and hardware in a manner that is capable of successfully competing with, if not altogether surpassing, CMB/LSIG image detail. This limitation is minimized further because there is no reason to believe that an upper limit on CGI performance is near.

In the area of visual technology, it is a conclusion of this study that CGI, with the advent of VSC level of performance, offers an acceptable replacement for CMB/LSIG technology, and provides many advantages in terms of supportability and flexibility. In addition, the opportunity for future gains in performance afforded by CGI far surpass those offered by CMB/LSIG.

d. Cost - In analyzing the operating and support costs relative to VSC introduction, many of the costs associated with this life cycle phase bear no direct link to the type of visual system. Those elements of cost which are affected are limited to electrical power requirements, space requirements, replenishment spares, and maintenance labor. These items are not expected to be significantly impacted by VSCDP technology, either positively or negatively. Actual unit cost is a risk at this time and will remain so until the full complexity of integrating all requirements is demonstrated. It is a conclusion of this study that the justification for introduction of VSC must come from other than simple economics; e.g., from training effectiveness which leads to higher probability of mission accomplishment and accident avoidance, reduction in required helicopter flight time, level of skill development/sustainment, etc.

e. Acquisition decisions - The VSCDP development schedule and a proposed follow-on production schedule were compared with current SFTS acquisition schedules and a table of VSC acquisition decision points was completed. Alternative courses of action were then selected and a cost analysis based upon each was completed. An

analysis of each alternative was then completed, leading to recommendations concerning visual technology application. (See paragraph 2.4.1 below.)

2.3.2 System Commonality

Commonality among existing and developmental SFTS simulators is analyzed separately in the area of instructional features, hardware and software. The interaction of commonality in each area as it effects the other two is also considered.

2.3.2.1 Instructional Features

Sixteen instructional features occurring in one or more simulator types are identified. Eight of these features are unique to the AH-64 CMS, while eight are common among all simulators comprising the SFTS. Standardization of instructional feature designs across future SFTS simulators would be a desirable goal, however, the instructional feature portion of SFTS design is its most rapidly developing and changing portion. Until much more instructional feature design stability is achieved, standardization would be ill advised. In that regard, it should be noted that eight of the sixteen instructional features in the AH-64 CMS were designed specifically for *that simulator* and have no counterparts among currently existing simulators, and there has been no operational experience with these features and therefore no opportunity to assess the suitability of their design. There can be no assurance that incorporation of these features in this present form in future simulators will be appropriate.

Instructional features, at this point in the development of training simulators, are largely experimental in design. They are intended to aid the instructor in the instructional process by allowing him to change the nature of the simulation (e.g., freeze) or by automating some portion of his task (e.g., target engagement exercise). To date, very few systematic efforts have been made to define precisely the need for an optimum design of instructional features, or to assess the suitability of their design with respect to the uses intended for them. Since the AH-64 CMS incorporates a number of innovative instructional features, some of which are designed specifically to render managable the instructor's workload in this complex simulation, specific efforts should be undertaken to assess their utility with a view toward enhancing this design for future Army simulators. It is believed that such efforts should be given high priority in the design of the next SFTS simulators, and discussion concerning their design and the standardization thereof should await the outcome of such efforts.

The following instructional features should be considered for upgrading SFTS simulators since they would enhance the training capability of those simulators.

- o Audio Record

  Of the record/playback functional and hardware differences between the various simulators, the digitized voice recording system would contribute to an improved training capability. The digitized voice system not only provides the audio voice capability for record/playback, but is used to provide voice for demonstrations. This system provides quicker access and a more precise synchronization of voice recordings.

- o Freeze Control

  Incorporation of the mushroom type switch to control freeze in the CH-47 FS, AH-I FWS, and AH-64 CMS would be an improvement and much more functional than the alternate action lighted switches currently being used.

- o Hardcopy

  Serious consideration should be given to changing the hardcopy print capability on SFTS production units to provide the instructor with the same capability that will exist in the AH-64 CMS.

- o Demonstration Preparation

  Incorporation of the demonstration preparation capabilities of the AH-64 CMS into existing SFTS simulators would facilitate the development by instructors of more useful and effective demonstrations for use with the simulator.

2.3.2.2 Hardware

Each simulator comprising the SFTS is found to require the same hardware functions: Motion system, computational system, visual system, instructor station, student station, maintenance and support equipment, and facilities interface. Existing common subassemblies and those that could be made common were determined from descriptions furnished by the SFTS prime contractor, a review of the specifications, and other requirements for each type simulator. Subassemblies which are common or prospectively common to two or more simulator types are recommended for commonality where predictable near-term technological advance offers no significant improvement in cost, availability, supportability, performance, energy utilization or safety.

The motion system is an excellent candidate for commonality among all SFTS models. Except for the platform which will be uniquely dimensioned to accomodate different cockpit configurations, full motion system commonality is being achieved for all present SFTS simulators, except for the UH-1 FS, and those under development. Since motion system drive signals are controlled by software to simulate helicopter motion and to provide motion cueing, a common motion system can be used universally on future SFTS simulators without modification, except as stated, as long as pay load capacity, excursion, velocity and acceleration limits are not required to be exceeded. The present common system need only be extended to new SFTS development to achieve commonality. Technological advances in hydraulics and specific motion system components are not expected to provide significant improvements in cost, availability, supportability, performance, energy utilization or safety over the next six to 12 years. Should components, materials or parts become unavailable due to manufacturer changes, shifts to new models and the like, such items can be replaced by those meeting the same form, fit and function requirements without materially altering the over all commonality of the system.

A common image generator which meets all present needs should be considered for use on SFTS simulators developed over the next ten to fifteen years, except for possible changes required to meet future needs, and the replacement of obsolete imbedded computers and other commercial equipment.

Technolgical developments in video image projection, eye tracking, scanning, projection optics and CRT displays are not advancing at a rapid rate. Once a display system is developed which satisfies all user needs, then this display system can become common for use on SFTS simulators developed over the next ten to fiften years. Common visionics displays can be used on SFTS simulators only where common visionics systems are provided on more than one helicopter.

2.3.2.3 Software

Significant functional similarity identified within the current and forth-coming SFTS software offers an opportunity for arriving at common software. Potential savings on the order of $30,000,000 could be realized over a twenty year period if maximum software commonality is obtained. Software that is to be considered for standardization must satisfy criteria of maintainability, reliability and tranportability. Although software being developed for the AH-64 CMS or for the production UH-60 FS may meet the conditions for standardization, the software now in

the Government inventory should not be considered for standardization without modifications to bring it into alignment with the criteria mentioned above. Commonality will not be achieved without a specific program to plan for and acquire common software. The potential benefits of Ada and the successful qualification of compilers for Ada indicate that use of Ada should play a major role in any SFTS common software initiative. A move to obtain common software within the SFTS is in alignment with DoD policy concerned with the reduction of post deployment software support costs. A significant element of commonality is the instantaneous aircraft data used in the simulation. To achieve software commonality, data commonality must also be addressed.

2.4 RECOMMENDATIONS

Recommendations are divided into the two major tasks undertaken in the study, Task A - Visual Technology Application and Task B - System Commonality. System commonality recommendations are provided separately for instructional features, hardware and software.

2.4.1 Recommendations for Visual Technology Application

a. That the Army standardize the Computer Generated Imagery (CGI) technical approach currently under development in the Visual System Component Develoment Program for visual system applications within the SFTS.

b. That action be taken to develop modular capabilities within the VSC that will allow the standard VSC to be tailored to particular simulator requirements.

c. That replacement of existing, otherwise satisfactory simulator visual systems with VSC be justified on the basis of new requirements as the data available for this study does not indicate cost savings when VSC is substituted to meet currently stated requirements.

2.4.2 Recommendations for System Commonality

2.4.2.1 Recommendations for Instructional Feature Commonality are:

a. That a program be initiated that will lead to an eventual standardized set of instructional features, beginning with evaluation of the new and modified features that are being implemented in the AH-64 CMS.

b. That this set of yet to be developed standard instructional features then serve as a library to satisfy user identified training requirements for new SFTS simulators.

2.4.2.2 Recommendations for Hardware Commonality are:

a. That action be taken to standardize the present motion base hardware.

b. That computer hardware systems not be subject to standardization actions.

c. That visual system standardization be approached as recommended for Visual Technology Application in 2.4.1 above.

d. That a program for standardization of instructor station components be initiated in conjunction with the program for instructional features recommended in 2.4.2.1.a. above.

e. That the student station not be considered for standardization at the subsystem level, though some component level standardization is possible in areas such as: Motion system warning light and deactivation, cockpit air conditioning, single or dual seat shaker as applicable, problem control panel and indicator, amplifier and speakers, safety items, control loading and aural cue generation.

f. That efforts be continued to ensure that standard tools and test equipment be utilized in support of the SFTS to the maximum extent possible.

2.4.2.3 Recommendations for Software Commonality are:

a. That a statement of policy be issued by PM TRADE endorsing the use of Ada on all future flight simulators and simulator upgrades, and stating that SFTS software/data commonality is a high priority goal for all future SFTS acquisition actions.

b. That immediate steps be taken to determine what degree of commonality can be required between the AH-64 CMS and the UH-60 FS within the scope of current contract activities.

c. That action be taken to develop an automated SFTS Data Element Dictionary using the tools available at the World Wide Software Support Center.

d. That a plan be developed for integrating all members of the SFTS into an Ada based common software environment.

3.0 VISUAL TECHNOLOGY APPLICATION

Visual technology application, within the scope and context of this report, ultimately implies its acquisition by PM TRADE.

This section of the report presents the analysis and subsequent results, which when considered together, produce a preliminary answer to the question: "What is the potential for applying advanced visual technology in the SFTS program?"

The acquisition analysis of visual system components addresses key items or considerations which impact critical decisions and decision points regarding the introduction of VSCDP technology.

Section 3.0 describes the methodology utilized to conduct this section of the study (i.e., 3.1, Methodology), the major subsections being separate yet interrelated analyses on:

a. Visual system acquisition actions anticipated over the next five to ten years (i.e., 3.2, Visual System Acquisition Plans).

b. An assessment of the impact of VSCDP technology on enhancing visual system performance for each type SFTS (i.e., 3.3, VSCDP Training Impact).

c. A cost analysis to determine the cost impact associated with alternative approaches to VSCDP technology acquisition (i.e., 3.4, VSCDP Cost Analysis).

d. A risk analysis of the VSCDP including an analysis of prevailing visual system concepts, completed and planned demonstrations/evaluations, and engineering data.

e. A comparison of the advantages and disadvantages among the various courses of action open for visual technology acquisition based on the intelligence derived from to the analyses conducted in steps a. through d. above (i.e., 3.6, Comparison of Acquisition Alternatives).

The reader will notice that this section is not a prescription on visual technology acquisition rather, a summary of issues to consider when contemplating the acquisition of advanced visual technology.

3.1 METHODOLOGY

The primary aim of Section 3.0 is to develop a coordinated plan for the successful introduction of advanced visual technology into the SFTS program. In developing such a plan, a systems approach was implemented utilizing the following steps:

a. Data collection to document information concerning the VSCDP, the SFTS (with special attention to plans for visual system acquisition), the state of development of the VSCDP candidates, and life cycle cost drivers.

b. Selection of alternative courses of action that represent acquisition options that are available in the near term to the SFTS.

c. Analysis of the alternative courses of action to determine advantages and disadvantages in terms of performance, life cycle costs, and technical risks.

d. Comparison of the advantages and disadvantages associated with each of the acquisition options.

e. Selection of the course of action that provides the most advantageous return on investment across the entire SFTS.

3.1.1 Data Collection Methodology

Data collection involved five principal sources. These sources include U.S. Army elements involved in flight simulator acquisition, utilization and support, and contractors currently developing visual systems for Army flight simulators. Both VSCDP contractors (Honeywell and General Electric) were visited to obtain status and performance data on their developments. Singer-Link, the supplier of present visual systems for the SFTS, was also visited to obtain a clear understanding of both current visual technology and the interface of visual systems to the various trainers making up the SFTS. The PM TRADE's Aviation Systems Division was the source of programmatic data on the SFTS and forthcoming acquisition actions. The U.S. Army Aviation Center was the source for training requirements and performance data.

3.1.2 Selection of Alternative Courses of Action

The five acquisition action options listed below are representative rather than all inclusive and should not be construed to preclude any number of combinations in determining the best approach in visual the technology acquisition. The anticipated acquisition actions offer five primary options:

a. Replace all Army Tactical Digital Image Generator (ATACDIG) and Model Board visual systems with VSCDP technology.

b. Replace all ATACDIG visual systems with VSCDP technology; retain Laser Scanning Image Generator (LSIG) Model Boards for their full life cycle. Use VSCDP technology on all future systems (e.g., LHX).

c. Replace all Model Board visual systems with VSCDP technology; retain all ATACDIG systems (except 2B40) for their full life cycle. Use VSCDP technology on all future systems.

d. Continue ATACDIG and LSIG systems for their full life cycle; use VSCDP on the 2B40 and all future systems.

e. Continue ATACDIG and LSIG systems; do not introduce VSCDP technology.

3.1.3 Determination of Advantages and Disadvantages

The capabilities of each visual system technology were analyzed to determine what advantages each technology offers in terms of skill/task training supported. Limitations were also identified. Supportability and availability were examined and used to estimate differences in life cycle costs for each alternative. Costs were estimated predicated on the assumptions that VSCDP technology will be available on schedule and that development costs are sunk (i.e., do not impact the cost trade-off).

3.1.4 Comparison of Alternatives

The comparison of alternatives was generally straightforward except that much will depend on future events in the VSCDP. Therefore, in addition to the straightforward, side-by-side comparison, certain conditional comparisons were addressed. These conditional comparisons were based on certain "what if?" assumptions about the progress of the VSCDP and indicate the impact of alternative outcomes to key events. (See Section 3.6.)

3.2 VISUAL SYSTEM ACQUISITION PLANS

The SFTS simulators in use presently and the planned acquisitions showing type and quantity of visual system included with each simulator are provided in Figure 3.2-1.

SYNTHETIC FLIGHT TRAINING SYSTEM VISUAL SYSTEM ACQUISITION PLANS

UNIT	TYPE VISUAL SYSTEM AND QUANTITY	CONTRACT AWARD FISCAL YEAR (C/A)	BUILDING OCCUPANCY DATE (BOD)	READY FOR TRAINING DATE (RFT)	INSTALLATION LOCATION
1. CH-47C CHINOOK Helicopter Flight Simulator, Device 2B31					
Prototype	* CMB		Oct 76	Jan 77	Ft. Rucker, AL
1	CMB (2)		Oct 81	May 82	Ft. Campbell, KY
2	CMB (2)		Dec 81	Aug 82	Ft. Hood, TX
3	CMB (2)		May 82	Nov 82	Mannheim, W. Germany
2. CH-47D CHINOOK Helicopter Flight Simulator, Device 2B31A - Version of Device 2B31 Updated to Simulate the D Model of the CH-47 Series Helicopter					
4	** ATACDIG	Sep 83	Apr 85	May 86	Ft. Lewis, WA
5	ATACDIG	Sep 83	Mar 86	Sep 86	Korea
Retrofit of Prototype and Production Units of Device 2B31 to the 2B31A Configuration.					
Prototype	ATACDIG	Apr 84	--	Jul 86	Ft. Rucker, AL
1	ATACDIG	Apr 84	--	Oct 86	Ft. Campbell, KY
2	ATACDIG	Apr 84	--	Jan 87	Ft. Hood, TX
3	ATACDIG	Apr 84	--	Apr 87	Mannheim, W. Germany
3. AH-1S COBRA Helicopter Flight Simulator, Device 2B33					
Prototype	CMB (2)	74	Jan 77	Mar 79	Ft. Rucker, AL
1	*** LSIG (2)	81	Aug 83	May 84	Ft. Hood, TX
2	LSIG (2)	82	Nov 83	Aug 84	Hanau, W. Germany
3	LSIG (2)	82	May 84	Jan 85	Ft. Campbell, KY
4	LSIG (2)	83	Aug 84	Apr 85	Illesheim, W. Germany

FIGURE 3.2-1

SYNTHETIC FLIGHT TRAINING SYSTEM VISUAL SYSTEM ACQUISITION PLANS (cont'd)

UNIT	TYPE VISUAL SYSTEM AND QUANTITY	CONTRACT AWARD FISCAL YEAR (C/A)	BUILDING OCCUPANCY DATE (BOD)	READY FOR TRAINING DATE (RFT)	INSTALLATION LOCATION
5	LSIG (2)	83	Nov 84	Jul 85	Ft. Lewis, WA
6	LSIG (2)	(84 ?)	Jul 85	Apr 86	Ft. Rucker, AL
7	LSIG (2)	(85 ?)	Oct 85	Jul 86	Ft. Indiantown Gap, PA (NG)
8	LSIG (2)	(85 ?)	Jan 86	Oct 86	Phoenix, AZ (NG)
4. UH-60 BLACK HAWK Helicopter Flight Simulator, Device 2B38					
Prototype (Two Units)	CMB (2) **** DIG I (1)			Apr 80	Ft. Rucker, AL
Lot I	Jan 84				
1	ATACDIG		Oct 85	May 86	Hanau, W. Germany
2	ATACDIG		Jan 86	Aug 86	Illesheim, W. Germany
3	ATACDIG		Apr 86	Nov 86	Ft. Campbell, KY
Lot II	ATACDIG	Dec 84			
4	ATACDIG		Jul 86	Feb 87	Ft. Campbell, KY
Prototype Retrofit (Two Units)	ATACDIG		--	May 87	Ft. Rucker, AL
5	ATACDIG		Jan 87	Aug 87	Ft. Lewis, WA
6	ATACDIG		Apr 87	Nov 87	Ft. Bragg, NC
7	ATACDIG		Jul 87	Feb 88	Ft. Hood, TX
Lot III	ATACDIG	Dec 85			
8	ATACDIG		Oct 87	May 88	Korea
9	ATACDIG		Jan 88	Aug 88	Hawaii
10	ATACDIG		Apr 88	Nov 88	Ft. Ord. CA
11	ATACDIG		Jul 88	Feb 89	Korea

FIGURE 3.2-1 (cont'd)

SYNTHETIC FLIGHT TRAINING SYSTEM VISUAL SYSTEM ACQUISITION PLANS (cont'd)

UNIT	TYPE VISUAL SYSTEM AND QUANTITY	CONTRACT AWARD FISCAL YEAR (C/A)	BUILDING OCCUPANCY DATE (BOD)	READY FOR TRAINING DATE (RFT)	INSTALLATION LOCATION
Lot IV	ATACDIG	Dec 86			
12	ATACDIG		Oct 88	May 89	Ft. Riley, KA
13	ATACDIG		Jan 89	Aug 89	Ft. Carson, CO
14	ATACDIG		Apr 89	Nov 89	Ft. Stewart, GA
15	ATACDIG		Jul 89	Feb 90	Ft. Polk, LA
5. AH-64 Apache Helicopter Combat Mission Simulator, Device 2B40					
Prototype	ATACDIG (2)	Jul 82	Nov 84	Aug 85	Ft. Rucker, AL
1	ATACDIG (2)	Feb 84	Jan 86	Aug 86	Ft. Hood, TX
2	ATACDIG (2)	Feb 84	Apr 86	Nov 86	Illesheim, W. Germany
3	ATACDIG (2)	Feb 84	Jun 86	Feb 87	Wiesbaden, W. Germa
4	ATACDIG (2)	Feb 84	Sep 86	May 87	Ft. Campbell, KY
5 (Option)	ATACDIG (2)	Feb 84	Dec 86	Aug 87	Ft. Rucker, AL
6 (Option)	ATACDIG (2)	Feb 84	Mar 87	Nov 87	Hanau, Germany

Legend:

* CMB = Camera Model Board

** ATACDIG = Army Tactical Digital Image Generator

*** LSIG = Laser Scanner Image Generator

**** DIG I = Digital Image Generator, First Generation

FIGURE 3.2-1 (cont'd)

3.2.1 Present Visual Systems

Two visual system types are presently in use in the SFTS. These are the Camera Model Board (CMB) system and a first generation Digital Image Generation (DIG I) system. Acquisition of additional quantities of these systems is not planned because of advances in both model board and computer image generation technology.

a. Camera Model Board. The camera model board system consists of a vertically mounted, three dimensional model board typically 24 feet high by 64 feet long with a gantry mounted color TV camera and optical probe. The TV camera viewpoint motion and view direction rotation are scaled to move in accordance with simulated flight maneuvers executed with the flight controls in the cockpit student station. Images from the TV camera simulating an out-the-window view are displayed on a wide-angle collimated (WAC) cathode ray tube (CRT) with a nominal 48° horizontal by 36° vertical FOV display positioned in a cockpit window. Multiple viewpoints are provided by adding CMBs. CMBs are modeled in detail with cultural and natural objects and terrain features, typically scaled at 1:1500. This scale provides an 11 by 29 kilometer gaming area with eye point locations from 10 to 1700 feet altitude and with cloud cover and sky simulated electronically above 1700 feet. Weapons effects, cloud cover, sky, chin window cues and other special effects are generated electronically. Eleven CMB visual systems are presently in use as follows:

	QUANTITY
o CH-47C FS, Device 2B31	
oo Prototype with a single CMB visual system.	1
oo Three production units with two CMB visual systems each.	6
o AH-IS FS, Device 2B33	
oo Prototype with two CMB visual systems.	2
o UH-60 FS, Device 2B38	
oo Prototype with two CMB visual systems.	2
TOTAL	11

b. Digital Image Generator (DIG I)

A single DIG I visual system is being used on a second prototype UH-60 FS. This is a four window, three channel visual system with right, left and front window WAC CRT displays (left and right front window sections share one channel). This system has a processing capacity of up to 4,000 edges at a 60Hz refresh rate, shared among the three visual channels. Take-off, landing, cross-country and formation flight training over a 40 by 40 nautical mile gaming area are provided. Special visual effects include a BLACK HAWK lead ship visual model and five moving tank visual models. The visual scene does not contain the near field detail, relative motion cues and ground surface formations and slopes to support nap-of-the-earth (NOE) flight simulation and training.

3.2.2 Visual Systems Presently in Production and Planned

Two visual system types are being developed and produced in conjunction with current SFTS acquisitions. These are the Laser Scanner Image Generator (LSIG) and the Army Tactical Digital Image Generator (ATACDIG) visual systems.

a. Laser Scanning Image Generator (LSIG)

Ten systems (two per SFTS) are presently under contract for production units one through five of the AH-IS FS, Device 2B33. Three additional AH-IS FS production units (requiring six additional LSIG systems) are planned for acquisition with contracts to be awarded in fiscal years 1984 and 1985. The LSIG visual system is similar to the CMB visual system. The LSIG uses the same dimensioned model board, gantry and servo controls with the TV camera and high intensity light bank replaced by a scanning multicolored laser beam and a bank of light sensitive photomultiplier tubes mounted in red, green and blue triads. The LSIG is scaled at 1:1000, providing more detail by using larger models than the 1:1500 CMB and reducing the gaming area to 7.3 by 19.3 kilometers. In addition, the high intensity light bank is eliminated, thereby reducing logistics support cost. Field of view (FOV) is 48° horizontal by 36° vertical.

b. Army Tactical Digital Image Generator (ATACDIG)

1. The ATACDIG visual system is being developed by the Link Advance Products Operation as part of the Link Flight Simulation Division's development of the prototype AH-64 CMS, Device 2B40. The prototype development contract was awarded in July 1982, and Government acceptance is scheduled for August 1985. In addition to the prototype, 35 ATACDIG systems are planned for production as follows:

		QUANTITY
o	AH-64 CMS (two per CMS) units 1 through 4	8
	Units 5 and 6 (options)	4
o	CH-47D FS (one per FS) units 5 and 6	2
	Prototype and units 1 through 3 (retrofit)	4
o	UH-60 FS (one per FS) units 1 through 15	15
	Prototypes units 1 and 2 (retrofit)	2
	TOTAL	35

2. The ATACDIG has been adapted from the prototype UH-60 FS DIG I visual system as improved in the DIG II visual system developed by Link for the Air Force B-52 Weapons System Trainer (WST) DIG system, and further modified to satisfy special requirements of the AH-64 CMS. Improvements over the prototype UH-60 FS DIG I have included and will include:

- o Numerous design changes devoted to additional test and diagnostic features.
- o *More powerful and easier to use diagnostic software.*
- o Increased processing capacity and efficiency achieved by small changes throughout the system and by the addition of the priority sectoring processor (PSP).
- o Improved scene complexity and realism with the addition of hardware texture providing enhanced cues for nap-of-the-earth (NOE) flight.
- o Improved data base generation and editing system.

Two ATACDIGs are required for the AH-64 CMS visual system to support integrated and independent pilot and copilot gunner (CPG) training, one for the pilot's cockpit displays and one for the CPG's cockpit displays. The pilot system has three channels which provide video to three wide-angle collimated CRT displays at the cockpit front and side windows when an out the window (OTW) scene is required. One of these three channels will be used to provide the Pilot Night Vision Sight (PNVS) Forward Looking Infrared (FLIR) wide-angle FOV to the pilot's Integrated Helmet and Display Sight System (IHADSS) Helmet Display Unit (HDU) or to the Visual Display Unit (VDU) on the pilot's instrument panel. When an OTW scene is required and the

CMS is operated in the integrated mode, the three-channel video is also displayed at the CPG WAC CRT displays.

The CPG ATACDIG provides one video channel which selectively simulates the Target Acquisition and Designation Sight (TADS) Direct View Optics (DVO), Daylight Television (DTV) or Forward Looking Infrared (FLIR) views, depending upon the operational mode selected. The DVO view is displayed only in the Optical Relay Tube (ORT) Head Down Display (HDD). The DTV and FLIR views are displayed on the CPG IHADSS HDU or on the ORT HDD or Head Out Display (HOD). When the CMS is operated in the integrated mode, the ORT displays, except for the DVO, can be monitored by the pilot on either the IHADSS HDU or on the VDU. Pilot and CPG displays can be monitored at respective instructor station visual repeater displays. A video routing switcher routes the correct video output to the correct display(s) depending upon the training mode (integrated - independent, day - night) and the display selections.

The AH-64 CMS ATACDIG performance characteristics include the following:

- Capacity: Normally 6,000 edges (or lights) at 60Hz update and with 512 edge intersections per scan line.
- TV and FLIR video: Processing to simulate actual operational sensor video output under various viewing conditions.
- Target and object level of detail: Four, with selection based upon magnification, range and processing capacity.
- Three WAC OTW CRT displays with the following field of view measured from the center of the CPG's front window vision plot:

VIEWS AND GAPS	FOV	
	VERTICAL	HORIZONTAL
Front	20° up to 20° down	15° left to 15° right
Gap (no view) Between Front and Side Views		15° left to 30° left 15° right to 30° right
Side	13° up to 35° down	30° left to 65° left 30° right to 65° right

- o Visionics display diagonal FOV: From 50° at 1x magnification (FLIR wide and PNVS) down to 0.9° at 61x magnification (DTV narrow) with zoom down to 0.45° at 122x magnification (DTV zoom).
- o Data Base: 32 kilometers by 40 kilometers gaming area.
- o Hardware texture developed for the prototype AH-64 CMS will be an individual option for each CMS to be procured under the AH-64 CMS production contract. Each option expires 12 months prior to the delivery date of the respective CMS.
- o Targets and special effects:
  - oo Fifteen target types, (articulated, non articulated, emitters, and traveling).
  - oo Ninety-nine target sites.
  - oo Ten targets per training scenario.
  - oo Five moving (traveling) targets per training scenario.
  - oo Ownship missiles.
  - oo Ownship missile impact effects.
  - oo Enemy fire impact effects.

The CH-47D FS and the UH-60 FS are expected use one ATACDIG three-channel WAC OTW visual system. These systems are essentially the same as the three-channel AH-64 CMS visual system, except that the CH-47D FS version will not include hardware texture and neither version will include visionics video processing.

3.2.3 Future Synthetic Flight Training System Development

A preliminary plan for the development of the LHX SCAT CMS and the LHX UTILITY FS is provided in Appendix A. This plan calls for the development of a simulator mix between SCAT CMS and UTILITY FS versions. VSCDP technology is planned for the LHX simulators.

Performance requirements and development plans for the OH-58D Helicopter FS and the Scout Attack Team Trainer (SATT) have not been defined (see Appendix A), and specific quantities, development schedules and production schedules have not been considered in this study. It should be recognized that the number of visual systems required for various type SFTS simulators will increase when and if

requirements for these systems are defined and approved and acquisition planning is started.

3.2.4 Visual System Component Development Program

The VSCDP is described in Appendix B. A production contract is planned for award in February 1986 for ten VSC production units with options for four additional units contingent upon: (1) VSC demonstrations to be completed by October 1985, (2) completion of a favorable developer's evaluation and report, and (3) evaluation of VSC production proposals. These VSCs will be retrofitted on AH-64 CMS under the Preplanned Product Improvement (P^3I) program in accordance with the following schedule:

VSC PRODUCTION UNITS	CMS RETROFIT UNITS	VSC DELIVERY; START INTEGRATION AND TESTING	COMPLETE TESTING (RFT)
1 and 2 First Articles	1	October 1987	July 1988
3 and 4	2	February 1988	November 1988
5 and 6	3	July 1988	April 1989
7 and 8	4	November 1988	August 1989
9 and 10	Prototype	April 1988	January 1990
11 and 12 (Option)	6	August 1989	May 1990
13 and 14 (Option)	7	December 1989	September 1990

Twenty months from contract award have been allowed for delivery of the first VSC for integration with an SFTS. This period includes the engineering development required to develop a production model VSC from the demonstrated brass board. It will not be prudent to attempt to deliver VSCs prior to October 1987. The production rate reflected in the above schedule (two VSCs delivered every fourth month) could be increased to provide additional visual systems for other simulators, if warranted. However, such production rates may not provide the most cost effective schedule, depending upon the total production quantity.

3.2.5 Visual System Acquisition Decision Points

Decision points to be analyzed are provided in Figure 3.2.5-1.

VISUAL SYSTEM ACQUISITION DECISION POINTS

ITEM	DESCRIPTION	EFFECT	DECISION POINT
1. CH-47D FS			
	a. Delete requirement to change CMB to ATACDIG visual systems during retrofit of prototype and production units 1 through 3 to D version FS.	Provide latest technology visual system at the expense of at least two years delay in replacing the CMB visual systems.	April 84 C/A
	b. Add requirement to the VSC production contract for four additional production VSCs for CH-47D FS, interface planning, hardware/software integration and testing.	Note that this delay would be initiated in 1984, before the final VSCDP demonstration in October 1985.	April 85, Planning February 86 C/A
	c. Contract with the CH-47D FS prime contractor for VSC/CH-47D FS interface planning and modification, hardware/software integration and testing of VSC retrofit replacement of CMB CH-47C visual systems.		April 85, Planning February 86 C/A
	d. Continue with present acquisition plans and replace CMB visual systems with ATACDIGs as scheduled. Retrofit FSs with VSC at a future date based upon CH-47D helicoptor service life beyond 20 years.		
2. AH-IS FS			
	a. Delay contract award for production units 6 through 8 from planned 1984 and 1985 dates to February 1986. Change RFP to delete LSIG requirement for these units and add requirement for interface planning, modification, hardware/software integration and testing of VSC visual systems.	*Provide latest technology visual systems in last* three production units at the expense of at least 29 months delay in the RFT dates. Note that this delay would be initiated in 1984 and 1985 before the final VSCDP demonstration in October 1985.	84 & 85 C/A February 86 C/A
	b. Add requirement to the VSC production contract for three additional production VSC visual systems for AH-IS FS, interface planning, installation, hardware/software integration and testing.		April 85 Planning February 86 C/A
	c. Retrofit FSs with VSC systems at future date based upon helicopter service life from 10 to 15 years from 1983.		
3. UH-60 FS			
	a. Change FS production contract requirement to delete ATACDIG visual systems from FSs to be delivered under Lot III, production units 8 through 11, and Lot IV, production units 12 through 15 and replace with VSC systems.	Provide latest technology visual systems in last eight production units.	December 85 (delay start on Lot III)
	b. Add requirement to the VSC production contract for eight additional production VSCs for UH-60 FS, interface planning hardware/software integration and testing.		April 85, Planning February 86 C/A

FIGURE 3.2.5-1

VISUAL SYSTEM ACQUISITION DECISION POINTS (cont'd)

ITEM	DESCRIPTION	EFFECT	DECISION POINT
	c. Contract with the UH-60 FS prime contractor for VSC/UH-60 FS interface planning and modification, hardware/software integration and testing of VSCs.		April 85, Planning February 86 C/A
4. AH-64 CMS	Present contract plans provide for either a multi-year type contract or an annual plus option year type contract. In the latter case, options can be exercised from one year (first unit) to three and one-half years (sixth unit) following contract award planned for February 1984. Options for units five and six under the multi-year type contract can be exercised up to February and August 1987 respectively. Should any option be exercised beyond February 1986, the planned production VSC contract award date, then the CMS could be equipped directly with VSC visual systems without retrofit.	For delayed options for additional CMS trainers exercised after February 1986, the procurement of two ATACDIG visual systems per CMS, later to be replaced with VSC systems, can be avoided. P^3I retrofit schedule would be amended to allow first VSCs delivered to be installed upon delayed option CMS deliveries.	August 85, Planning February 86 C/A
5. LHX CMS and FS	Acquisition plans should provide for VSC systems for LHX and other future helicopter CMS and FS developments either by separate CMS/FS and VSC contracts or by the VSC procurement being a specified subcontract to the CMS/FS prime contract.	Provide latest technology visual system for all CMS/FS acquisition planned following VSC development.	86 to 91 Time Frame

FIGURE 3.2.5-1 (cont'd)

3.3 VSCDP TRAINING IMPACT

A requirement of the present effort is to assess the potential training effectiveness of the VSCDP and to assess the training advantages, if any, of replacing the AH-64 CMS visual system (i.e., ATACDIG) with a display developed through VSCDP technology at some time in the future. A related requirement is to assess the training advantages of replacing other SFTS visual systems with VSCDP technology. This section of the report describes the analyses that were conducted in order to make the required training effectiveness assessments and the results that were derived from them.

3.3.1 Background For The Visual Analysis

In 1980, an analysis was conducted of the design of the AH-64 CMS[1] as proposed at that time. As part of that study, a detailed examination was conducted of the computer-generated image visual system technology specified for the CMS. The purpose of the examination was to identify the kinds of visual information needed by pilots and copilot/gunners to perform tasks that were representative of those to be performed in the AH-64 helicopter and to assess the capabilities of the CMS visual system technology to provide the required visual information. Eighteen types of such visual information were identified. They are described below.[2]

1. Vertical movement: low altitude -- detection or awareness of movement of the aircraft either up or down relative to the ground or ground-based objects.

2. Horizontal movement: low altitude -- detection or awareness of movement of the aircraft in any direction in a plane parallel to the ground.

3. Drift: low altitude — detection or awareness of movement during a hover, in or out of ground effect, very slow and of low magnitude, in a horizontal plane.

4. Linear acceleration or deceleration: low altitude -- detection or awareness of change in horizontal or vertical velocity, either speeding up or slowing down.

5. Rate of closure: vertical -- awareness of continuous change in "nearness" to the ground or to an object below the aircraft at look-down angles; may

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[1]Caro, P. W., Spears W. D., Isley, R. N. & Miller, E. J. Analysis of the design of an AH-64 combat mission simulator (Seville Tech. Rep. TR 80-17). Pensacola, FL: Seville Research Corporation, December 1980.

[2]These descriptions are quoted from Caro et al., op. cit., pp. 9-10

characterize approaching the ground or object, if in an ascent, may characterize moving away from the ground or object (negative closure).

6. Rate of closure: horizontal -- awareness of continuous change in "nearness" of an object in the aircraft plane of motion; may characterize approaching the object or moving away from it (negative closure).

7. Rate of turn -- awareness of continuous change in heading as related to task requirements.

8. Bank angle -- awareness of the status of the lateral plane of the aircraft relative to the ground, horizon, or objects in the plane of aircraft movement.

9. Altitude: low level -- knowledge of distance of the aircraft above the ground in feet or in terms of task requirements (e.g., altitude proper for NOE flight; altitude adequate to clear an obstacle).

10. Distances of objects and terrain features -- knowledge of distance to objects and portions of the terrain in meters or in terms of tasks requirements (e.g., navigation; maneuvering with respect to objects).

11. Heights of objects and terrain -- knowledge of heights of objects and terrain in feet or in terms of task requirements (e.g., maneuvering with respect to the objects and terrain).

12. Range -- knowledge of distance of a target (range estimation) in a common metric (e.g., meters) that aids in attack tasks.

13. Directional orientation -- knowledge of terrain features relative to location of the aircraft, navigational requirements, and task requirements necessary to maintain spatial and aerial orientation.

14. Terrain features -- recognizable characteristics of the terrain such as its nature, contours, ground cover, and relative heights of various portions of the terrain.

15. Rotor distance -- an intuitively meaningful metric based on rotor radius that can be used to maneuver and maintain clearance when among near objects.

16. Peripheral context -- visual scene characteristics not in the area of interest but necessary for overall motion and orientation cues and feedback, and for preventing confusion in the scene.

17. Object features — recognizable characteristics of objects that enable recognition of the kind of object (tank, trunk, tree, etc.) and shape.

18. Object details — recognizable characteristics of objects, including texture, that aid in their identification (e.g., friendly versus hostile tanks) or in judging distances from them when close.

The 1980 study of AH-64 CMS visual display requirements also identified 51 representative tasks to be performed in the AH-64 helicopter, and determined, through pilot interviews and analyses of the technical literature on visual perception, which of the 18 visual information types is/are primary to the performance of each task. Information is primary if it is necessary for providing feedback or in cueing, monitoring, and implementing appropriate pilot or copilot/gunner task performance. The 51 tasks are listed in Figure 3.3.1-1. The types of visual information primary to performance of each task are indicated in Figure 3.3.1-1 by Xs in the appropriate columns.

	TASKS	VERTICAL MOVEMENT: LOW ALTITUDE	HORIZONTAL MOVEMENT: LOW ALTITUDE	DRIFT: LOW ALTITUDE	LINEAR ACCEL OR DECEL: LOW ALTITUDE	RATE OF CLOSURE: VERTICAL	RATE OF CLOSURE: HORIZONTAL	RATE OF TURN	BANK ANGLE	ALTITUDE: LOW LEVEL	DISTANCE OF OBJECTS	HEIGHTS OF OBJECTS AND TERRAIN	RANGE	DIRECTIONAL ORIENTATION	TERRAIN FEATURE IDENTIFICATION	ROTOR DISTANCE	PERIPHERAL CONTEXT	OBJECT DETAIL	OBJECT FEATURES
DEPARTURE	TAKEOFF TO HOVER, CLEARING OTHER AIRCRAFT, OBSTACLES, ETC.		X		X					X							X		X
	ASCEND TO ALTITUDE FOR LOW LEVEL FLIGHT				X					X	X	X		X	X		X		X
	FOLLOW DESIGNATED COURSE IN STRAIGHT AND LEVEL FLIGHT				X	X	X				X	X			X		X		X
	SCAN AREA FOR ENEMY THREATS		X								X	X						X	X

PRIMARY VISUAL INFORMATION TYPES RELEVANT TO PERFORMANCE OF PILOT AND CPG TASKS DURING A TYPICAL AH-64 ATTACK MISSION

FIGURE 3.3.1-1

PRIMARY VISUAL INFORMATION TYPES RELEVANT TO PERFORMANCE OF PILOT AND CPG TASKS DURING A TYPICAL AH-64 ATTACK MISSION (CONTINUED)

	TASKS	VERTICAL MOVEMENT: LOW ALTITUDE	HORIZONTAL MOVEMENT: LOW ALTITUDE	DRIFT: LOW ALTITUDE	LINEAR ACCEL OR DECEL: LOW ALTITUDE	RATE OF CLOSURE: VERTICAL	RATE OF CLOSURE: HORIZONTAL	RATE OF TURN	BANK ANGLE	ALTITUDE: LOW LEVEL	DISTANCE OF OBJECTS	HEIGHTS OF OBJECTS AND TERRAIN	RANGE	DIRECTIONAL ORIENTATION	TERRAIN FEATURE IDENTIFICATION	ROTOR DISTANCE	PERIPHERAL CONTEXT	OBJECT DETAIL	OBJECT FEATURES
CONTOUR FLIGHT	IDENTIFY POINT OF ENTRY INTO CONTOUR FLIGHT		X			X	X				X	X		X	X		X		X
	IDENTIFY POINT TO BEGIN DESCENT TO CONTOUR FLIGHT					X	X				X	X		X	X		X		X
	MAINTAIN CONSTANT ANGLE OF DESCENT TO CONTOUR POINT OF ENTRY				X					X	X	X		X	X		X		X
	DECELERATE DESCENT TO ZERO LEVEL AT CONTOUR HEIGHT	X	X		X	X	X			X	X	X		X	X		X		X
	PROCEED ON COURSE MAINTAINING CONSTANT HEIGHT ABOVE TERRAIN/VEGETATION		X			X	X				X	X			X				X
	SCAN AHEAD FOR CHANGES IN CONTOURS OF TERRAIN/VEGETATION		X			X	X				X	X		X	X		X		X
	SCAN AREA FOR ENEMY THREATS		X								X	X						X	X

FIGURE 3.3.1-1 (CONT)

PRIMARY VISUAL INFORMATION TYPES RELEVANT TO PERFORMANCE OF PILOT AND CPG TASKS DURING A TYPICAL AH-64 ATTACK MISSION (CONTINUED)

	TASKS	VERTICAL MOVEMENT: LOW ALTITUDE	HORIZONTAL MOVEMENT: LOW ALTITUDE	DRIFT: LOW ALTITUDE	LINEAR ACCEL OR DECEL: LOW ALTITUDE	RATE OF CLOSURE: VERTICAL	RATE OF CLOSURE: HORIZONTAL	RATE OF TURN	BANK ANGLE	ALTITUDE: LOW LEVEL	DISTANCE OF OBJECTS	HEIGHTS OF OBJECTS AND TERRAIN	RANGE	DIRECTIONAL ORIENTATION	TERRAIN FEATURE IDENTIFICATION	ROTOR DISTANCE	PERIPHERAL CONTEXT	OBJECT DETAIL	OBJECT FEATURES
NOE FLIGHT	IDENTIFY POINT OF ENTRY INTO NOE FLIGHT		X			X	X				X	X		X	X		X		X
	IDENTIFY POINT TO BEGIN DESCENT TO NOE LEVEL		X			X	X			X	X	X		X	X		X		X
	DESCEND TO NOE HEIGHT, ADJUSTING ANGLE TO AVOID OBSTACLES AND UTILIZE MASK				X	X	X			X	X	X		X	X				X
	FLY MASKING, RANDOM ZIG-ZAG COURSE CLOSE TO MASKING COVER		X				X			X	X	X			X	X		X	X
	SCAN AHEAD TO ANTICIPATE ADJUSTMENTS IN FLIGHT PATH/ALTITUDE		X				X			X	X	X		X	X		X	X	X
	RECOGNIZE CHANGES IN CONTOURS OF TERRAIN						X			X	X	X		X	X		X	X	X
	RECOGNIZE CHARACTERISTICS OF MASKING COVER						X			X	X	X		X	X		X	X	X
	RECOGNIZE OBSTACLES					X	X				X	X		X	X			X	X
	MAINTAIN NOE HEIGHT ABOVE TERRAIN	X	X			X				X	X	X		X	X	X			
	MAXIMIZE PROTECTIVE COVER WHILE AVOIDING COLLISIONS WITH TERRAIN, COVER, ETC.										X	X		X	X	X		X	X

FIGURE 3.3.1-1 (CONT)

PRIMARY VISUAL INFORMATION TYPES RELEVANT TO PERFORMANCE OF PILOT AND CPG TASKS DURING A TYPICAL AH-64 ATTACK MISSION (CONTINUED)

	TASKS	VERTICAL MOVEMENT: LOW ALTITUDE	HORIZONTAL MOVEMENT: LOW ALTITUDE	DRIFT: LOW ALTITUDE	LINEAR ACCEL OR DECEL: LOW ALTITUDE	RATE OF CLOSURE: VERTICAL	RATE OF CLOSURE: HORIZONTAL	RATE OF TURN	BANK ANGLE	ALTITUDE: LOW LEVEL	DISTANCE OF OBJECTS	HEIGHTS OF OBJECTS AND TERRAIN	RANGE	DIRECTIONAL ORIENTATION	TERRAIN FEATURE IDENTIFICATION	ROTOR DISTANCE	PERIPHERAL CONTEXT	OBJECT DETAIL	OBJECT FEATURES
NOE FLIGHT (CONTINUED)	ALTER ZIG-ZAG FLIGHT PATH TO FOLLOW CONTOURS OF MASK	X	X		X	X	X	X	X	X	X	X		X	X		X	X	X
	ALTER FLIGHT PATH TO AVOID OBSTACLES	X	X		X	X	X	X	X	X	X	X		X	X				X
	ALTER ALTITUDE TO FOLLOW CONTOURS OF TERRAIN	X	X		X	X	X	X	X	X	X			X	X				X
	ALTER ALTITUDE TO AVOID OBSTACLES		X		X	X	X	X	X	X	X			X	X	X			X
	INCREASE ALTITUDE WHEN HEIGHT OF MASKING COVER PERMITS		X		X	X	X		X	X	X			X	X	X			X
	PERFORM CLIMBING/DESCENDING TURNS TO FOLLOW TERRAIN/MASK CONTOURS		X		X	X	X			X	X	X						X	X
	DECELERATE TO NEGOTIATE CHANGES IN HEADING AND ALTITUDE	X				X	X			X	X	X		X	X			X	X
	ACCELERATE TO MAXIMUM SAFE SPEED WHEN CONDITIONS PERMIT					X	X			X	X	X		X	X			X	X
	SCAN TERRAIN FOR ORIENTATION	X					X				X			X	X				X
	MAINTAIN ORIENTATION TO FIRING POSITION AND TARGET										X	X		X	X				X

FIGURE 3.3.1-1 (CONT)

PRIMARY VISUAL INFORMATION TYPES RELEVANT TO PERFORMANCE OF PILOT AND CPG TASKS DURING A TYPICAL AH-64 ATTACK MISSION (CONTINUED)

	TASKS	VERTICAL MOVEMENT: LOW ALTITUDE	HORIZONTAL MOVEMENT: LOW ALTITUDE	DRIFT: LOW ALTITUDE	LINEAR ACCEL OR DECEL: LOW ALTITUDE	RATE OF CLOSURE: VERTICAL	RATE OF CLOSURE: HORIZONTAL	RATE OF TURN	BANK ANGLE	ALTITUDE: LOW LEVEL	DISTANCE OF OBJECTS	HEIGHTS OF OBJECTS AND TERRAIN	RANGE	DIRECTIONAL ORIENTATION	TERRAIN FEATURE IDENTIFICATION	ROTOR DISTANCE	PERIPHERAL CONTEXT	OBJECT DETAIL	OBJECT FEATURES
NOE FLIGHT (CONT)	IDENTIFY COURSE CHECKPOINTS										X				X		X	X	X
	SCAN AREA FOR THREATS		X								X	X						X	X
FIRING POSITION OPERATIONS	IDENTIFY DESIGNATED FIRING POSITION										X				X				X
	EVALUATE CONFIGURATION OF FIRING POSITION MASKING COVER									X					X			X	X
	SELECT MASKED LOCUS FOR ATTACK OPERATIONS									X					X			X	X
	PERFORM CONFINED AREA APPROACH AND DESCENT TO HOVER/LANDING		X	X	X	X	X	X	X	X	X	X		X		X	X		X
	COMPLETE PREPARATIONS FOR WEAPONS RELEASE																		
	ASCEND TO HOVER (IF ON GROUND)			X		X	X			X					X	X	X		X
	ALIGN AIRCRAFT WITH TARGET AZIMUTH			X										X			X		X
	ASCEND TO MINIMUM HEIGHT FOR DIRECT LINE OF SIGHT TO TARGET, AND HOVER			X		X	X			X	X	X		X		X	X		X

FIGURE 3.3.1-1 (CONT)

PRIMARY VISUAL INFORMATION TYPES RELEVANT TO PERFORMANCE OF PILOT AND CPG TASKS DURING A TYPICAL AH-64 ATTACK MISSION (CONTINUED)

	TASKS	VERTICAL MOVEMENT: LOW ALTITUDE	HORIZONTAL MOVEMENT: LOW ALTITUDE	DRIFT: LOW ALTITUDE	LINEAR ACCEL OR DECEL: LOW ALTITUDE	RATE OF CLOSURE: VERTICAL	RATE OF CLOSURE: HORIZONTAL	RATE OF TURN	BANK ANGLE	ALTITUDE: LOW LEVEL	DISTANCE OF OBJECTS	HEIGHTS OF OBJECTS AND TERRAIN	RANGE	DIRECTIONAL ORIENTATION	TERRAIN FEATURE IDENTIFICATION	ROTOR DISTANCE ·	PERIPHERAL CONTEXT	OBJECT DETAIL	OBJECT FEATURES
FIRING POSITION OPERATIONS (CONTINUED)	DETECT AND IDENTIFY TARGET												X					X	X
	ASCEND TO MINIMUM HEIGHT FOR WEAPONS TO CLEAR MASKING COVER	X		X		X	X			X	X	X		X	X		X		
	MAINTAIN STABLE HOVER AND ALIGNMENT WITH TARGET	X		X										X	X				X
	ACQUIRE AND ENGAGE TARGET												X	X				X	X
	MONITOR RWR DURING ATTACK																X		
	IDENTIFY GROUND-BASED THREATS DURING ATTACK										X		X	X			X	X	X
	AIM 30mm GUN AT THREATS AND DELIVER SUPPRESSIVE FIRE										X		X	X			X		X
	ASSESS DAMAGE TO TARGET													X				X	X
	DESCEND TO MASKED ALTITUDE			X		X				X	X	X		X		X	X		X
	DEPART FIRING POSITION	X			X			X	X	X	X	X		X			X		

FIGURE 3.3.1-1 (CONT)

3.3.2 Approach

The approach followed in the assessment of the potential training effectiveness of the VSCDP and other SFTS visual systems built upon the visual analysis conducted during the 1980 study. In conducting the assessment, 49 of the 51 tasks[1] analyzed during the 1980 study were rated with respect to each of the information types identified in Figure 3.3.1-1 as primary to each task. Separate ratings were made for each visual display system technology application, i.e., for the VSCDP, for the computer-generated visual image currently being developed for the AH-64 CMS, for the Digital Image Generation visual system (DIG I), and for a nonspecific Camera Model Board (CMB) visual system such as that currently incorporated into the design of the CH-47 FS and the AH-1 FS at Fort Rucker or the laser image system under development for production units of the AH-1 FS[2]. Unweighted mean ratings were then computed for each task (i.e., each row) and for each information type (i.e., each column), and these ratings provided a basis for comparison of the relative potential training effectiveness of the four visual system technologies by task and by visual information type.

A 4-point rating scale was used. The scale values reflected the judged training efficiency of the respective visual system technology application with respect to the tasks and visual information types rated. A scale value of 0 indicated that the

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[1] Two of the tasks included in the 1980 analysis could be performed without use of information derived through the visual system and were not included in the present analysis. These tasks were "Complete Preparation for Weapons Release" and "Monitor RWR During Attack."

[2] In assessing the relative merits of the technology applications involved in the visual systems and in rating each, each technology application was considered to be at its very best. That is, each technology application rated was considered to be producing the optimum image that it was capable of generating. The model board technology did not specifically address the boards at Fort Rucker, but rather the highest quality imagery that technology can produce. For comparison of a specific model board visual system with a digital image system, the reader is referred to the following documents:

Cirone, E. A. UH60FS/CH47FS Continuation Training Special Study Final Letter Report Fort Rucker, Alabama: United States Army Aviation Board, December 1982.

Luckey, J. R. et al Operational Test II Phase I of the UH-60A Black Hawk Operational Flight Simulator (OT II, Phase I UH60FS) Final Test Report Fort Rucker, Alabama: United States Army Aviation Board, April 1982.

Campbell, F. D. and Slavin, L. F. Independent Evaluation Report on the UH-60 Flight Simulator (UH60FS) Fort Rucker, Alabama: Directorate of Training Development, United States Army Aviation Center, January 1983.

visual system was judged to provide little if any visual information useful for training the task in question. A value of three indicated that the visual system could provide training virtually as easily as could comparable training in the aircraft using "real world" visual cues.[3] The intermediate scale values reflect the extent to which mediational processes would be required to achieve effective training with the visual system being rated. A scale value of one would indicate a need for relatively extensive use of mediation in the instructional process; a value of two a need for relatively little mediation. Thus, the higher the scale value, the more efficient and effective the visual system was judged to be with respect to the items being rated.

"Mediation," as used here in reference to the assignment of ratings, refers to the need to resort to ways of processing visual cues that are not necessary with real-world scenes. For example, a DIG I representation of a hill at a moderate distance may not provide texture, size, and linear perspective cues sufficient for estimating its distance. The observer may attempt to supplement the view of the hill by scanning terrain around it, even in his peripheral field of view, so as to place the hill in a context. This behavior is rapid and automatic with real scenes, but it may entail deliberate trade-offs of cueing sources in an incomplete scene. If so, the extra scanning and trade-offs are mediational approaches to distance perception that are over and above those required with real-world scenes. It is the amount of extra mediational effort that governed assignments of ratings of one and two. Note that in providing the extra effort required, especially for one ratings, the student may learn modes of scanning and perceptual processing at odds with those to be used in the aircraft. Therefore, it could be desirable, at least for those tasks characterized by ratings of one, to intersperse aircraft and simulator experiences so as to maintain discriminations among habits appropriate to each.

The ratings were made by two team members familiar with the visual system technologies being rated. These personnel had experience with both the DIG I and CMB visual systems at Fort Rucker, had reviewed the capabilities of the Laser Scanning Image Generator (LSIG) system under development for the AH-1 FS production units, had participated in the development of the ATACDIG system for the AH-64 CMS, and had seen demonstrations of VSCDP technology applications conducted by the VSCDP contractors. Because three of the four visual system technology

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[3]The context for these ratings was concerned solely with the utility of the "natural" visual cues. Thus, the training utility of other aspects of simulator training--for example, the capability of freezing the simulator, thus allowing detailed analysis or explanation of a visual scene--was not considered in this analysis.

applications rated in the present study are "composite" systems, or are systems under development and can only be viewed during limited scope demonstrations, the ratings should not be considered definitive in any absolute sense. Instead, the mean scale values derived for each task and information type should be viewed only as an indication of the relative order of merit of the respective systems for the items rated.

3.3.3 Results

The unweighted mean scale values obtained during the visual system technology application assessments described above are presented in Figures 3.3.4-1, -2 and -3. The overall mean for each application, obtained by totaling the ratings for each of the applications and dividing by the number of items rated (as indicated in Figure 3.3.1-1), are in Figure 3.3.4-1. Figure 3.3.4-2 contains the mean ratings for each of the 49 pilot and copilot tasks rated. It should be noted that ratings are not presented for firing position-related tasks for the DIG I visual system because the UH-60 FS, the only Army simulator that has the DIG I visual, has no weapon simulation capability. Figure 3.3.4-3 contains the mean ratings for each information type. These mean ratings were obtained by summing the individual ratings assigned to each primary visual information type applicable to each task and dividing by the number of types rated for that task (Figure 3.3.4-2), or by summing those ratings applicable to each information type and dividing by the number of tasks rated for that information type (Figure 3.3.4-3). The tasks and information types involved in each of these computations are identified in Figure 3.3.1-1.

3.3.4 Discussion

The principal question of interest in the present study in whether the potential training value of the VSCDP visual system technology will be sufficiently greater than the training value of the ATACDIG visual system being developed with the AH-64 CMS to justify the cost and other impacts of replacing the ATACDIG visual system with a visual system based upon the VSCDP technology. Similar questions relate to replacing CMB and DIG I visual systems with visual systems based upon VSCDP technology. In the final analysis, the answer to these questions will be based upon judgments of the relative training value of the technologies concerned. The analyses that are described above can provide information that can help support such judgments.

The mean scale values in Figure 3.3.4-1 give an indication of the relative training value of the various visual technology applications assessed. Generally, these ratings are in line with expectations. The DIG I visual system has been rated as having limited training value. Nevertheless, with mediation, i.e., in a carefully designed and administered training program that attends specifically to the mediational processes employed, some effective visual task training can be and, in fact, is being conducted in it.

MEAN TRAINING EFFECTIVENESS RATINGS FOR FOUR VISUAL SYSTEM TECHNOLOGY APPLICATIONS	
Visual System Task Application	**Mean Rating**
DIG I	1.34
CMB/LSIG	2.34
CMS ATACDIG	1.62
VSCDP	2.39

FIGURE 3.3.4-1

It should be noted that the overall rating of the DIG I would probably have been lower if the firing position tasks had been included in its assessment. The DIG I is relatively less useful for visual tasks that involve operation close to objects and surfaces or that require discrimination of image detail. Further, because of the very limited capability of the DIG I to show object detail, visual information that would facilitate performance of tasks involving estimation of distance to and relative size of objects is not easily derived.

The ATACDIG visual system was rated as having higher training value than the DIG I system in spite of the fact that it suffers from the same kinds of design limitations that constrain the DIG I system. Both systems are very similar in the technology they employ. The principal difference is the increased detail that can be presented in the ATACDIG because of its greater edge capacity. This ATACDIG capability for increased detail is particularly important in tasks that involve firing position operations, e.g., detection of small shifts in position relative to trees and terrain, target detection, and damage assessment. Even there, however, the training

UNWEIGHTED MEAN RATINGS OF THE TRAINING EFFICIENCY OF VISUAL DISPLAY TECHNOLOGY APPLICATION FOR ARMY HELICOPTER PILOT AND COPILOT/GUNNER TASKS

TASKS TO BE PERFORMED	VISUAL DISPLAY TECHNOLOGY APPLICATION			
	DIG I	CMB	ATACDIG	VSCDP
DEPARTURE:				
1. Takeoff to hover, clearing other aircraft, obstacles, etc.	1.2	2.6	2.0	2.6
2. Ascend to altitude for low level flight	1.2	2.4	1.4	2.1
3. Follow designated course in straight and level flight	1.2	2.4	1.6	2.1
4. Scan area for enemy threats	0.8	0.8	0.8	1.4
CONTOUR FLIGHT:				
5. Identify point of entry into contour flight	1.6	2.7	1.9	2.7
6. Identify point to begin descent to contour flight	1.5	2.6	1.9	2.6
7. Maintain constant angle of descent to contour point of entry	1.5	2.5	1.6	2.5
8. Decelerate descent to zero level at contour height	1.5	2.4	1.5	2.3
9. Proceed on course maintaining constant height above terrain/vegetation	1.3	2.3	1.3	2.3
10. Scan ahead for changes in contours of terrain/vegetation	1.4	2.2	1.6	2.0
11. Scan area for enemy threats	0.8	0.8	0.8	1.4
NOE FLIGHT:				
12. Identify point of entry into NOE flight	1.4	2.6	2.0	2.7
13. Identify point to begin descent to NOE level	1.3	2.7	1.9	2.6
14. Descent to NOE height, adjusting angle to avoid obstacles and utilize mask	1.2	2.4	1.3	2.2
15. Fly masking, random zig-zag course close to masking cover	1.3	2.1	1.6	2.2

FIGURE 3.3.4-2

UNWEIGHTED MEAN RATINGS OF THE TRAINING EFFICIENCY OF VISUAL DISPLAY TECHNOLOGY APPLICATION FOR ARMY HELICOPTER PILOT AND COPILOT/GUNNER TASKS (cont'd)

TASKS TO BE PERFORMED	VISUAL DISPLAY TECHNOLOGY APPLICATION			
	DIG I	CMB	ATACDIG	VSCDP
NOE FLIGHT: (Continued)				
16. Scan ahead to anticipate adjustments in flight path/altitude	1.5	2.3	1.7	2.0
17. Recognize changes in contours of terrain	1.3	2.3	1.6	2.0
18. Recognize characteristics of masking cover	1.3	2.4	1.4	2.7
19. Recognize obstacles	1.4	2.5	1.8	2.6
20. Maintain NOE height above terrain	1.2	2.3	1.4	2.3
21. Maximize protective cover while avoiding collisions with terrain, cover, etc.	1.1	2.1	1.4	2.4
22. Alter zig-zag flight path to follow contours of mask	1.6	2.4	1.8	2.4
23. Alter flight path to avoid obstacles	1.4	2.6	1.7	2.6
24. Alter altitude to follow contours of terrain	1.5	2.3	1.6	2.3
25. Alter altitude to avoid obstacles	1.5	2.5	1.7	2.5
26. Increase altitude when height of masking cover permits	1.2	2.6	1.3	2.6
27. Perform climbing/descending turns to follow terrain/mask contours	1.3	2.1	1.4	2.1
28. Decelerate to negotiate changes in heading and altitude	1.2	2.5	1.5	2.4
29. Accelerate to maximize safe speed when conditions permit	1.2	2.7	1.4	2.4
30. Scan terrain for orientation	1.3	2.2	1.4	2.2
31. Maintain orientation to firing position and target	--	2.3	1.5	2.3
32. Identify course checkpoints	1.4	2.6	1.6	2.8
33. Scan area for threats	0.8	0.8	0.8	1.4
FIRING POSITION OPERATIONS:				
34. Identify designated firing position	--	2.7	2.0	2.7

FIGURE 3.3.4-2 (cont'd)

UNWEIGHTED MEAN RATINGS OF THE TRAINING EFFICIENCY OF VISUAL DISPLAY TECHNOLOGY APPLICATION FOR ARMY HELICOPTER PILOT AND COPILOT/GUNNER TASKS (cont'd)

TASKS TO BE PERFORMED	VISUAL DISPLAY TECHNOLOGY APPLICATION			
	DIG I	CMB	ATACDIG	VSCDP
FIRING POSITION OPERATIONS: (Continued)				
35. Evaluate configuration of firing position masking cover	--	3.0	1.8	3.0
36. Select masked locus for attack operations	--	2.8	1.8	3.0
37. Perform confined area approach and descent to hover/landing	--	2.6	2.1	2.8
38. Complete preparations for weapons release	--	--	--	--
39. Ascend to hover (if on ground)	--	2.6	1.8	2.9
40. Align aircraft with target azimuth	--	2.8	2.8	3.0
41. Ascend to minimum height for direct line of sight to target, and hover	--	2.4	1.7	2.7
42. Detect and identify target	--	1.0	1.0	1.3
43. Ascend to minimum height for weapons to clear masking cover	--	2.2	1.8	2.4
44. Maintain stable hover and alignment with target	--	2.6	2.0	3.0
45. Acquire and engage target	--	1.2	1.0	1.2
46. Monitor RWR during attack	--	--	--	--
47. Identify ground-based threats during attack	--	1.3	1.2	1.3
48. Aim 30mm gun at threats and deliver suppressive fire	--	2.2	1.6	2.0
49. Assess damage to target	--	0.3	1.0	1.0
50. Descend to masked altitude	--	2.7	1.9	2.9
51. Depart firing position	--	3.0	2.0	3.0

FIGURE 3.3.4-2 (cont'd)

UNWEIGHTED MEAN RATINGS OF THE TRAINING EFFICIENCY OF VISUAL DISPLAY TECHNOLOGY APPLICATIONS FOR VISUAL INFORMATION TYPES

VISUAL INFORMATION TYPE	VISUAL DISPLAY TECHNOLOGY APPLICATION			
	DIG I	CMB	ATACDIG	VSCDP
Vertical Movement: Low Altitude	1.4	2.2	1.9	2.6
Horizontal Movement: Low Altitude	1.9	2.2	2.0	2.4
Drift: Low Altitude	--	2.6	2.1	2.9
Linear Accel or Decel: Low Altitude	1.2	2.4	1.4	2.4
Rate of Closure: Vertical	1.0	2.5	1.5	2.5
Rate of Closure: Horizontal	1.3	2.5	1.5	2.5
Rate of Turn	3.0	3.0	3.0	3.0
Bank Angle	3.0	3.0	3.0	3.0
Altitude: Low Level	1.2	2.6	1.3	2.6
Distance of Objects	1.0	1.8	1.1	1.8
Heights of Objects and Terrain	0.9	2.2	1.3	1.9
Range	--	1.8	1.0	1.0
Directional Orientation	2.0	2.4	2.0	2.4
Terrain Feature Identification	1.0	2.8	1.6	2.4
Rotor	0.0	0.0	1.0	2.0
Peripheral Context	1.7	3.0	2.0	3.0
Object Detail	0.8	1.6	1.5	2.0
Object Features	1.9	2.7	1.9	2.8

FIGURE 3.3.4-3

value of the ATACDIG suffers from lack of ability to present object detail, but the limitation is not as severe as with the DIG I.

In planning for use of the AH-64 CMS with the ATACDIG visual technology application, particular care must be paid to the design and administration of the training program to be used with it. Care to the mediational processes to be employed can have a major effect upon the effectiveness of most of the training to be conducted with the ATACDIG visual system.

In terms of their overall ratings, the CMB and VSCDP visual system technology applications appear to be about equally suitable for training the tasks of interest in the present study. Assuming optimum application of the respective technologies, the increased level of detail that would be available can make a significant difference, compared to the DIG I and the ATACDIG, in the potential training effectiveness to that derived through use of the CMB and VSCDP. The complexity or "richness" of the scene presented through these two technologies make them much more "realistic" in appearance, thereby decreasing the extent to which mediational processes will be critical to their effective use.

Although their overall ratings are similar, the CMB and VSCDP visual applications differ with respect to their effectiveness for training specific tasks. Tasks involving distance and object identification tend to have an advantage with the CMB, whereas tasks that require discrimination of fine detail favor the VSCDP. The reasons for these differences are that more visual information is inherently possible using the CMB technology, since it involves video images of a model board that by its nature must be complete and continuous. By contrast, there is a limit to the amount of visual information that can be deployed in any affordable computer-generated system, although creative distribution of scene content (information) can lessen the impact of that limit. Offsetting this advantage of the CMB, however, is the fact that much sharper images can be presented employing the VSCDP technology, thereby making fine discrimination possible during performance of some visual tasks. The slightly higher mean rating given the VSCDP for firing position tasks requiring discrimination of fine detail reflects this difference. The fact that CMB technology has limited flexibility to depict changing scene content, such as is required to depict a rotor disc, weapons effects, and target damage, is also reflected in the ratings of tasks where such dynamics are needed for effective training without resort to mediation.

3.4 VSCDP COST ANALYSIS

3.4.1 Purpose

Each of the five alternative courses of action listed in section 3.1.2 carries cost implications for both acquisition, fielding/installation, as well as operation and support. To compare the cost implications, the alternatives are individually examined and a cost profile for each is presented.

3.4.2 Cost Methodology

The general methodology that was employed in developing costs for each of the alternatives was as follows:

a. Assumptions were developed to define the costs presented and to provide a common framework for comparison.

b. Data was collected as part of the applied analysis techniques used in developing the coordinated plan for introduction of VSCDP to SFTS.

c. Hypothetical schedules for production award and ready-for-training were developed for each alternative, with attention given to availability of VSCDP technology, rate of production, and sequence of installed or retrofitted visual systems. These schedules serve to time phase estimated funding requirements. See Figures 3.4.3-1 through 3.4.3-5. To derive the five hypothetical schedules, the principal drivers in establishing the initial ready for training date was the expected availability of production VSC as noted in Appendix B, Production VSC Milestones for the AH-64 CMS P^3I Retrofit. Thereafter a gradual production build-up was applied until a maximum production rate of one VSC per month was achieved. Since VSC will be available in July 1988, integration of VSC to future simulators (e.g., LHX) can be accomplished without retrofit; i.e., during normal production. Hence, VSC was scheduled for inclusion in the LHX during normal production, delaying in some cases the retrofit of existing simulators (with VSC) until after May 1997. As an example, refer to the schedule for Alternative A. In chronological sequence, first units scheduled for VSC are the retrofit of all AH-64 CMS, followed by retrofit of all AH-IS FS units, then retrofit of a portion of the UH-60 FS, followed by VSC production for LHX (to retrofit), and finally return to the retrofit of the balance of UH-60 FS and the CH-47D FS.

VSCDP SCHEDULE FOR ALTERNATIVE A (REPLACE ALL CGI AND MODEL BOARD SYSTEMS WITH VSCDP)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
1. AH-64 CMS	1	2	2	Feb. 1986	July 1988
2B40	2	2	4	Feb. 1986	Nov 1988
	3	2	6	Feb. 1986	April 1989
	4	2	8	Feb. 1986	Aug 1989
	Prototype	2	10	Feb. 1986	Jan 1990
	6 (Option)	2	12	FY 88	May 1990
	7 (Option)	2	14	FY 88	Sept 1990
2. AH-IS FS	Prototype	2	16	FY 89	Jan 1991
2B33	1	2	18	FY 89	April 1991
	2	2	20	FY 89	June 1991
	3	2	22	FY 89	Aug 1991
	4	2	24	FY 89	Dec 1991
	5	2	26	FY 89	Feb 1992
	6	2	28	FY 89	April 1992
	7	2	30	FY 89	June 1992
	8	2	32	FY 89	Aug 1992
3. UH-60 FS	Prototype	1	33	FY 90	Dec 1992
2B38	Prototype	1	34	FY 90	Jan 1993
	1	1	35	FY 90	Feb 1993
	2	1	36	FY 90	Mar 1993
	3	1	37	FY 90	Apr 1993
	4	1	38	FY 90	May 1993
	5	1	39	FY 90	June 1993
	6	1	40	FY 95	June 1997
	7	1	41	FY 95	July 1997
	8	1	42	FY 95	Aug 1997
	9	1	43	FY 95	Sept 1997

FIGURE 3.4.3-1

VSCDP SCHEDULE FOR ALTERNATIVE A (REPLACE ALL CGI AND MODEL BOARD SYSTEMS WITH VSCDP) (cont'd)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
UH-60 FS	10	1	44	FY 95	Oct 1997
(continued)	11	1	45	FY 95	Nov 1997
	17	1	46	FY 95	Dec 1997
	13	1	47	FY 95	Jan 1998
	14	1	48	FY 95	Feb 1998
	15	1	49	FY 95	Mar 1998
4. CH-47D FS	Prototype	1	50	FY 96	April 1998
2B31	1	1	51	FY 96	May 1998
	2	1	52	FY 96	June 1998
	3	1	53	FY 86	July 1998
	4	1	54	FY 96	Aug 1998
	5	1	55	FY 96	Sept 1998
5. LHX*	Prototype 1 to 3	1 ea	58	FY 88	Oct 1991 Mar 1996 Oct 1992
	Production 1 to 48	1 ea	106	FY 92	June 1993 thru May 1997, at rate of one VSCDP per month

* This data listed in association with the LHX is highly speculative and is used soley for the purpose of this study.

FIGURE 3.4.3-1 (cont'd)

VSCDP SCHEDULE FOR ALTERNATIVE B (REPLACE ALL CGI WITH VSCDP; RETAIN ALL LSIG USE VSCDP ON FUTURE ACQUISITION)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
1. AH-64 CMS	1	2	2	Feb 86	July 1988
2B40	2	2	4	Feb 86	Nov 1988
	3	2	6	Feb 86	April 1989
	4	2	8	Feb 86	Aug 1989
	Prototype	2	10	Feb 86	Jun 1990
	6 (Option)	2	12	FY 88	May 1990
	7 (Option)	2	14	FY 88	Sept 1990
2. UH-60 FS	Prototype	1	15	FY 89	Jan 1991
2B38	Prototype	1	16	FY 89	Mar 1991
	1	1	17	FY 89	May 1991
	2	1	18	FY 89	June 1991
	3	1	19	FY 89	July 1991
	4	1	20	FY 89	Aug 1991
	5	1	21	FY 89	Sept 1991
	6	1	22	FY 89	Nov 1981
	7	1	23	FY 89	Dec 1991
	8	1	24	FY 89	Jan 1992
	9	1	25	FY 89	Feb 1992
	10	1	26	FY 89	Mar 1992
	11	1	27	FY 89	April 1992
	12	1	28	FY 89	May 1992
	13	1	29	FY 89	June 1992
	14	1	30	FY 89	July 1992
	15	1	31	FY 89	Aug 1992
3. CH-47D FS	4	1	32	FY 91	Dec 1992
2B31	5	1	33	FY 91	Jan 1993

FIGURE 3.4.3-2

VSCDP SCHEDULE FOR ALTERNATIVE B (REPLACE ALL CGI WITH VSCDP; RETAIN ALL LSIG USE VSCDP ON FUTURE ACQUISITION) (cont'd)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
	Prototype	1	34	FY 91	Feb 1993
	1	1	35	FY 91	Mar 1993
	2	1	36	FY 91	April 1993
	3	1	37	FY 91	May 1993
4. LHX*	Prototypes 1 to 3	1 ea	40	FY 88	Oct 1991 Oct 1992 Nov 1992
	Production	1 ea	88	FY 92	July 1993 thru June 1997 at rate of one VSCDP per month

* This data listed in association with the LHX is highly speculative and is used soley for the purpose of this study.

FIGURE 3.4.3-2 (cont'd)

VSCDP SCHEDULE FOR ALTERNATIVE C (REPLACE ALL MODEL BOARDS WITH VSCDP; RETAIN ALL ATACDIG EXCEPT AH-64 CMS; USE VSCDP ON ALL FUTURE ACQUISITIONS)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
1. AH-64 CMS 2B40	1	2	2	Feb 86	July 1988
	2	2	4	Feb 86	Nov 1988
	3	2	6	Feb 86	Apr 1989
	4	2	8	Feb 86	Aug 1989
	Prototype	2	10	Feb 86	Jan 1990
	6 (Option)	2	12	FY 88	May 1990
	7 (Option)	2	14	FY 88	Sept 1990
2. AH-1S FS 2B33	Prototype	2	16	FY 89	Jan 1991
	1	2	18	FY 89	Apr 1991
	2	2	20	FY 89	June 1991
	3	2	22	FY 89	Aug 1991
	4	2	24	FY 89	Dec 1991
	5	2	26	FY 89	Feb 1992
	6	2	28	FY 89	Apr 1992
	7	2	30	FY 89	June 1992
	8	2	32	FY 89	Aug 1992
3. LHX*	Prototypes 1 to 3	1 ea	35	FY 88	Oct 1991 Oct 1992 Nov 1992
	Production 1 to 48	1 ea	83	FY 92	June 1993 thru May 1997, at rate of one VSCDP per month

* This data listed in association with the LHX is highly speculative and is used soley for the purpose of this study.

FIGURE 3.4.3-3

VSCDP SCHEDULE FOR ALTERNATIVE D (CONTINUE DIG II AND LSIG; USE VSCDP ON AH-64 CMS AND ALL FUTURE ACQUISITIONS)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
1. AH-64 CMS 2B40	1	2	2	Feb 86	July 1988
	2	2	4	Feb 86	Nov 1988
	3	2	6	Feb 86	Apr 1989
	4	2	8	Feb 86	Aug 1989
	Prototype	2	10	Feb 86	Jan 1990
	6 (Option)	2	12	FY 88	May 1990
	7 (Option)	2	14	FY 88	Sept 1990
2. LHX*	Prototypes 1 to 3	1 ea	17	FY 88	Oct 1991 Oct 1992 Nov 1992
	Production 1 - 48	1 ea	65	FY 92	June 1993 thru May 1997, at rate of one VSCDP per month

* This data listed in association with the LHX is highly speculative and is used soley for the purpose of this study.

FIGURE 3.4.3-4

VSCDP SCHEDULE FOR ALTERNATIVE E (CONTINUE DIG II AND LSIG; USE VSCDP ONLY ON ALL FUTURE ACQUISITIONS)

SIMULATOR	UNIT	QTY OF VSC	CUM QTY OF VSC	VSC PROD. CONTRACT AWARD	RFT
1. LHX*	Prototype 1	1	1	FY 88	Oct 1991
	Prototype 2	1	2	FY 88	Oct 1992
	Prototype 3	1	3	FY 88	Nov 1992
	Production 1 to 48	1	51	FY 92	June 1993 thru May 1997, at rate of one VSCDP per month

* This data listed in association with the LHX is highly speculative and is used soley for the purpose of this study.

FIGURE 3.4.3-5

3.4.3 Assumptions

The baseline assumptions listed below were established for a variety of reasons, the most essential of which was to enable a meaningful comparison of cost estimates among alternatives. The assumptions are intended to be reasonable in nature in view of the alternatives under consideration, and further serve to define the implication of the estimates presented. Any necessary assumptions that are unique to one alternative are included in the discussion of that alternative. The following assumptions are therefore universal in nature and apply to each alternative.

a. Costs are presented in millions of FY84 constant dollars.

b. VSCDP technology is developed and available in accordance with the current plans. Reference paragraph 3.2.4, Visual System Acquisition Plans.

c. Introduction of VSCDP technology has no impact on the number of instructors required for any of the simulators within the SFTS family.

d. Introduction of VSCDP technology has no impact on training time for any of the system devices within the SFTS family. Note: While training time is assumed to be unaffected, the possibility remains that flight time in the various aircraft can be replaced with flight simulator time, resulting in potential training cost savings.

e. Visual systems in place and operating, as well as the development cost of LSIG, ATACDIG and VSCDP are considered sunk. Therefore, replacing any fielded visual system with VSCDP will incur costs for production, installation (and check out), and operating and support. A salvage value of zero is assumed for replaced systems.

f. Time phasing of investment (production) costs assume a full funding concept; i.e., full production funding will occur in the year of contract award.

g. Figures relating to the LHX are assumptions for the purpose of this study only.

3.4.4 Results

A first unit production cost of $9.752* is derived as follows:

Production Cost for 10 Units	$	95.630	(FY 82 $)
Non-recurring cost		(3.127)	(FY 82 $)
In-House Government costs		(.699)	(FY 82 $)
Retrofit (separately priced)		(3.606)**	
Subtotal	$	88.198	(FY 82 $)
Cost Per Unit (÷10)	$	8.820	(FY 82 $)
Cost in FY 84 Constant $ (x1.1057)	$	9.752	

* Source for all data: Validated Baseline Cost Estimate, dated 18 November 1982, for AH-64 CMS (Device 2B40), paragraph 2.11.2.1, page 92.

** Retrofit cost included in cost profiles as a separate cost line; see Figure 3.4.4-3.

An 85% experience curve is applied to the first unit cost in order to calculate total production costs at various quantities. Results at the various quantities (coincident to quantities shown in the schedules, Figures 3.4.3-1 through 3.4.3-5) are charted in Figure 3.4.4-1. Unit costs are plotted in Figure 3.4.4-2. Using the schedules together with the calculated production costs at appropriate quantity levels, cost profiles for each of the alternatives are generated. The cost profiles are given in millions of constant FY 84 $ in Figure 3.4.4-3.

3.4.5 Analysis and Conclusions

There are several reasons for selecting the 85% learning curve. The current Visual System Component (VSC) developers were surveyed in order to guage the expected trend in VSC production costs. The responses are a major contributor to the estimation of an appropriate learning curve slope. One of the most important results of the survey is the unanimous opinion that cost reductions through the learning curve phenomenon will not be inconsequential. The opinion is based on the nature of the hardware that is expected to comprise a VSC. An evaluation of the nature of the hardware shows that a significant part of the system will be electronic.

Much of these electronics will be of recent technology. As regards the technology of computers, it is in a changing state. Significant advances are expected over the next 3-5 years that will permit higher and higher concentrations of capability in smaller packages. This is especially true of Random Access Memory (RAM), and since a part of the VSC will apply large blocks of RAM, it can be expected that this technological evolution will yield smaller computer packages for the VSC.

The visual display sections of VSC will also apply new technology, except for the dome, light valves and other commercial products that may be present. New technology offers opportunities for cost reduction through simplification of hardware design as well as manufacturer production familiarization and process improvements both items are contributors to the experience curve phenomonon.

The schedules for production of VSC, prepared for each of the alternatives A through E in Figure 3.4.4-3, include the assumption that production of VSC will be relatively continuous; i.e., production interruptions will be kept to a minimum. In addition, after a period of build-up, the rate of production is kept constant at one VSC each month. Both of the factors contribute to steady state production and result in a means to reduce costs. To summarize, an 85% curve was selected as applicable to production of VSC for the following reasons:

VSC PRODUCTION COST AT 85% EXPERIENCE CURVE (CONSTANT FY 84 $ MILLIONS)				
VSCDP UNITS	85% EXPERIENCE CURVE CUMULATIVE TOTAL FACTOR	CUMULATIVE RECURRING PROD. COST	AVG. UNIT COST AT LISTED QTY	UNIT COST OF:
1	1.000	$ 9.752	$ 9.752	1st unit - $ 9.752
2	1.8500	18.041	9.021	2nd unit - 8.289
3	2.6229	25.579	8.526	3rd unit - 7.537
10	7.1161	69.396	6.940	10th unit - 5.683
17	10.8977	106.274	6.251	17th unit - 5.018
34	18.8593	183.916	5.409	34th unit - 4.266
35	19.2938	188.153	5.376	35th unit - 4.237
40	21.4252	208.936	5.223	40th unit - 4.107
42	22.2601	217.080	5.169	42nd unit - 4.060
51	25.9109	252.683	4.955	51st unit - 3.879
65	31.3071	305.307	4.697	65th unit - 3.665
83	37.8629	369.239	4.449	83rd unit - 3.460
88	39.6225	386.399	4.391	88th unit - 3.413
90	40.3198	393.199	4.369	90th unit - 3.396
106	45.7757	446.405	4.211	106th unit - 3.268

FIGURE 3.4.4-1

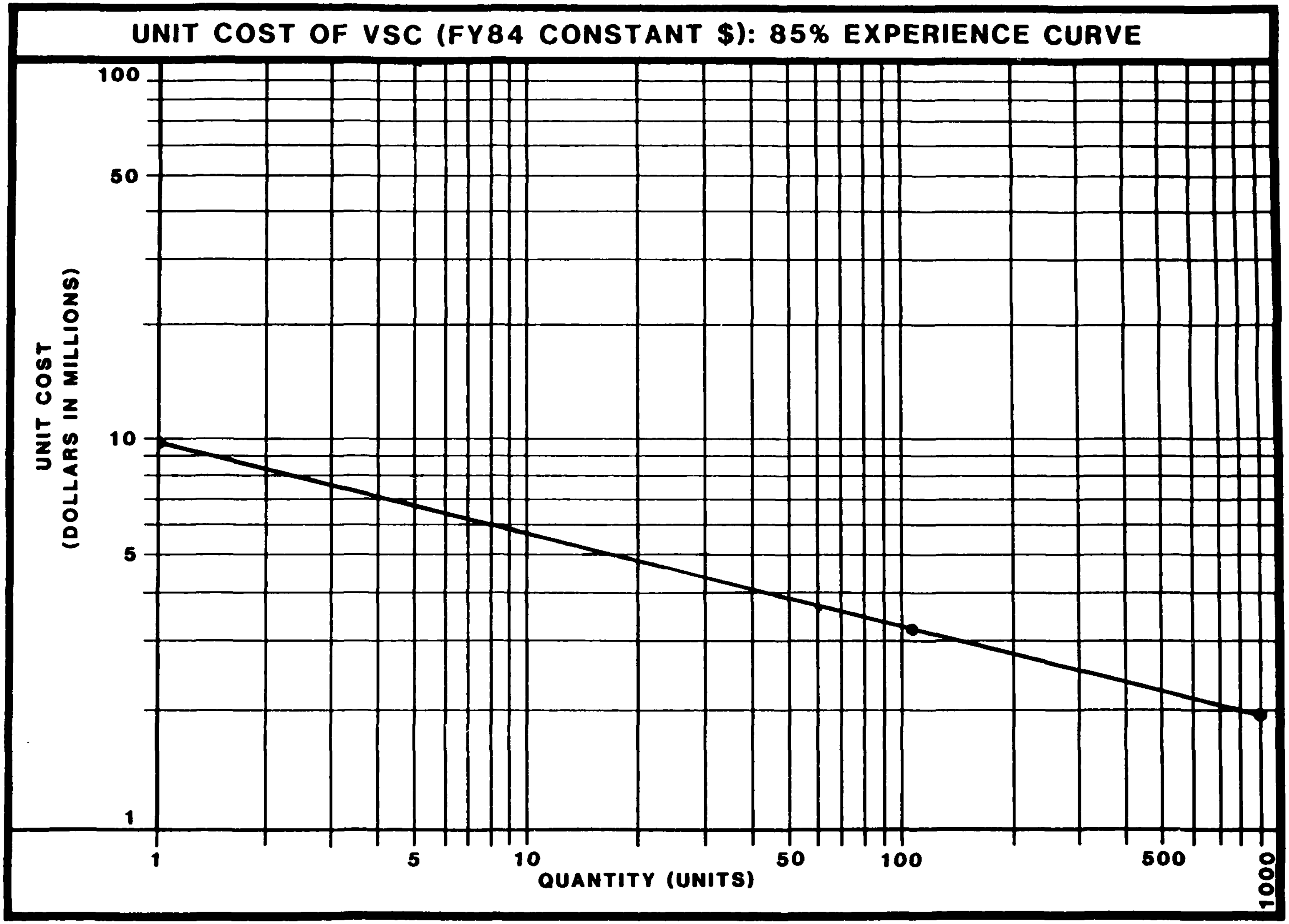
UNIT COST OF VSC (FY84 CONSTANT $): 85% EXPERIENCE CURVE
UNIT COST
(DOLLARS IN MILLIONS)
100
50
10
5
1
1
5
10
50
100
500
1000
QUANTITY (UNITS)

FIGURE 3.4.4-2

INVESTMENT COST PROFILES FOR VISUAL SYSTEM COMPONENTS
(CONSTANT FY 84 $Millions)

Fiscal Year =	86	87	88	89	90	91	92	93	94	Out Years	Total
Alternative A: Quantity Awarded	10	--	7	18	7	--	48	--	--	16	106
Quantity RFT	--	--	2	6	6	8	11	12	12	49	106
Production	$ 69.4	--	$ 36.9	$ 81.9	$ 28.9	--	$ 176.1	--	--	$ 53.2	$ 446.4
Retrofit	--	--	0.7	2.2	2.2	$ 2.9	3.6	$ 2.5	--	5.8	19.9
O&S	--	--	21.8	23.5	24.6	24.8	25.3	28.2	$ 34.0	739.9	922.1
Total Cost	$ 69.4		$ 59.4	$ 107.6	$ 55.7	$ 27.7	$ 205.0	$ 30.7	$ 34.0	$ 798.9	$1,388.4
Alternative B: Quantity Awarded	10	--	7	17	--	6	48	--	--	--	88
Quantity RFT	--	--	2	6	6	7	11	11	12	33	88
Production	$ 69.4	--	$ 36.9	$ 77.6	--	$ 25.0	$ 177.5	--	--	--	$ 386.4
Retrofit	--	--	0.7	2.2	$ 2.2	2.5	3.6	$ 2.2	--	--	13.4
O&S	--	--	21.8	23.5	24.6	24.8	25.3	28.2	$ 34.0	$ 739.9	922.1
Total Cost	$ 69.4		$ 59.4	$ 103.3	$ 26.8	$ 52.3	$ 206.4	$ 30.4	$ 34.0	$ 739.9	$1,321.9
Alternative C: Quantity Awarded	10	--	7	18	--	--	48	--	--	--	83
Quantity RFT	--	--	2	6	6	8	11	6	12	32	83
Production	$ 69.4	--	$ 36.9	$ 81.9	--	--	$ 181.1	--	--	--	$ 369.3
Retrofit	--	--	0.7	2.2	$ 2.2	$ 2.9	3.6	--	--	--	11.6
O&S	--	--	21.8	23.5	24.6	24.8	25.3	$ 28.2	$ 34.0	$ 739.9	922.1
Total Cost	$ 69.4		$ 59.4	$ 107.6	$ 26.8	$ 27.7	$ 210.0	$ 28.2	$ 34.0	$ 739.9	$1,303.0
Alternative D: Quantity Awarded	10	--	7	--	--	--	48	--	--	--	65
Quantity RFT	--	--	2	6	6	--	1	6	12	32	65
Production	$ 69.4	--	$ 36.9	--	--	--	$ 199.0	--	--	--	$ 305.3
Retrofit	--	--	0.7	$ 2.2	$ 2.2	--	--	--	--	--	5.1
O&S	--	--	21.8	23.5	24.6	$ 24.8	25.3	$ 28.2	$ 34.0	$ 739.9	922.1
Total Cost	$ 69.4		$ 59.4	$ 25.7	$ 26.8	$ 24.8	$ 224.3	$ 28.2	$ 34.0	$ 739.9	$1,232.5

FIGURE 3.4.4-3

INVESTMENT COST PROFILES FOR VISUAL SYSTEM COMPONENTS

(CONSTANT : Y 84 $Millions) (cont'd)

Fiscal Year =	86	87	88	89	90	91	92	93	94	Out Years	Total
Alternative E: Quantity Awarded	--	--	3	--	--	--	48	--	--	--	51
Quantity RFT	--	--	--	--	--	--	1	6	12	32	51
Production	--	--	$ 25.6	--	--	--	$ 227.1	--	--	--	$ 252.7
Retrofit	--	--	--	--	--	--	--	--	--	--	--
O&S	--	--	21.8	$ 23.5	$ 24.6	$ 24.8	25.3	$ 28.2	$ 34.0	$ 739.9	922.1
Total Cost	--		$ 47.4	$ 23.5	$ 24.6	$ 24.8	$ 252.4	$ 28.2	$ 34.0	$ 739.9	$1,174.8

FIGURE 3.4.4-3 (cont'd)

- o A survey of the current VSC developers indicates a significant reduction in cost due to changes in electronic packaging.
- o Production is sufficient in rate, quantity, and continuity to permit development of more efficient tools.
- o Production is sufficient ' rate, quantity, and continuity to permit reductions in management or efficient changes in organization.
- o New technology engineering problems will be solved.

Note: Both of the current VSCDP developers, GE and Honeywell, have indicated that a substantial learning curve effect will occur with VSC program.

- o An 85% learning curve is typical of electronics production.

To analyze operating and support costs for VSC, the Department of Army Pamphlet (DA Pam) Number 11-4 was used to identify the various elements of cost that will occur in this phase of its life cycle. An assessment of how or if VSC will impact each cost element was made. Those elements are as follows:

a. Instructor Pay and Allowances.

b. Consumption.

c. Depot Maintenance.

d. Modifications.

e. Other Direct Support Operations.

f. Indirect Support Operations.

Item a., instructor pay and allowances, is unaffected by introduction of VSCDP. A premise of the cost part of this study assumes that training time will not be positively or negatively affected.

Item b., consumption, normally includes replenishment spares, petroleum/oil/lubricants, and ammunition/missiles. Consideration of petroleum, ammunition, etc. can be excluded; they apply to flight simulators only in a very minor role. Since the VSC is planned to be contractor supported, replenishment spares are discussed under item e., other direct support operations. Therefore no analysis of consumption is meaningful.

Item c., depot maintenance, requires no analysis, again, since the system will be contractor maintained, and no military operated depot facilities will exist.

Item d., modifications, is an element of cost usually resulting from changes to the operational aircraft. Therefore, any flight simulator system regardless of the type of visual system is equally subject to modification. Introduction of VSCDP will not drive the cost of modifications.

Skipping to item f., indirect support operations, the costs collected in this element are related to those military personnel assigned solely to the system. These costs include personnel replacement related costs, medical support, maintenance and utilities for quarters, etc. In the case of VSCDP, these personnel include only the instructors. Hence VSC will have no cost impact with respect to instructors, due to the same reasoning applied to item a., instructor pay and allowances.

Returning to the sole remaining element, item e., other direct support operations, is the collection point for any remaining costs associated directly with the system, in this case VSCDP. Costs of this element include as follows:

- o Facilities Power Requirements.
- o Facilities Custodial, Maintenance, or other Utilities.
- o Trainer System Power Requirements.
- o Contractor Maintenance, which includes,
  - oo Replenishment Spares
  - oo Maintenance Labor

Reviewing this final set of subelements in the same sequence they appear above, facilities power requirements are a function of floor space, the volume of the building enclosure (for heating or cooling), and the volume of heat dissipated by the trainer. Of the visual systems in existence and planned for procurement, only the first one with light banks opposite the model boards generate sufficient heat to be a significant cost driver. The VSCDP likewise will not generate large amounts of heat, and therefore, does not represent a significant cost differential as compared to DIG I, ATACDIG or LSIG visual systems. Similarly, the VSCDP is not expected to produce significantly lower quantities of heat. The floor space requirements for systems with VSCDP may be larger, but not significantly larger. (Current space for existing equipment ranges from 14,000 to 16,000 square feet.) Therefore, custodial or building maintenance costs, the second subelement will not be affected by VSCDP.

Power requirements for simulators range from a high of 787 kw per hour of operation (two CMB visual system) to a low of 308 kw per hour (two LSIG visual system). Requirements for the UH-60 FS with a DIG system have been calculated at 346 kw per hour. Based on expectations for VSCDP compared to these power useages, no significant differences are expected.

The single remaining item for evaluation is contractor maintenance, composed of the replenishment spares and maintenance labor. The quantity of required spares are a function of the level of utilization of the system, marginal design, component part failure rates and the overall size/complexity of the system. The total cost of spares, in turn, is a function of the quantity required and the purchasing system. Introduction of VSCDP will not of itself raise significantly the level of trainer use. With respect to marginal design and failures, only thorough design engineering, including reliability/cost trade-offs, will improve these factors. There are no reasons to suggest that the design of VSC will result in either improved or poorer overall design. However, too much haste during the VSCDP and transition into production increases the risk of marginal design or inadequate parts being specified, and hence increases the potential for costly operation.

The VSC will be a larger visual system, in terms of components and complexity, than its predecessors. Cost of replenishment spares for any system tend to be proportional to the value of the materials and parts used in its manufacture. The estimated average unit cost of the VSC in a quantity of 14 units (sufficient to equip seven AH-64 CMS) is $6.5*. This compares favorably with Singer Link's estimate for an LSIG system at $6.9** for a quantity of ten units, sufficient to equip five AH-IS FS. It could therefore be concluded that VSC will not cause a significant increase or decrease in the cost of replenishment spares. To the Army's benefit, procurement of spares, both replenishment and initial, is centralized through Singer-Link's logistics function (part of the maintenance support contract) at Fort Rucker. This centralized procurement function for all simulator sites results in the combined procurement of all spare needs.

The final item of contractor maintenance, and the final element of cost in the operations and support area, is maintenance labor. As with replenishment spares, a portion of the maintenance labor activity is linked to the level of use and failure

* First unit cost of $9.752 at 85% experience curve (factor: .6665)
** Validated BCE of 10 March 1982 for AH-1 (Device 2B33), based on Singer proposal.

	ITEM	DATE (On or before)
D/E 1	Proof of Concept Demonstration	Apr 84
D/E 2	Display/Image Generator Demonstation	Jan 85
D/E 3	VSCDP Demonstration, Test and Evaluation	
	a. Technical	Sep 85
	b. Operational Suitability	Oct 85

Additional contractor tests and investigations are being conducted during VSCDP with tests being observed by Government personnel and/or with results reported at technical reviews and in technical submittals. VSCDP contract delivery items affording additional opportunities for risk assessment during development include the following:

ITEM	DATE (On or before)
Preliminary Design Review	Oct 83
Trainer Engineering Report, updated quarterly	Dec 83 - Dec 85
Critical Design Review	Mar 84
Quarterly Progress Review	Jun 84 - Sep 85

Risk areas listed in Figure 3.5-1 show where in the contract schedule these areas will be demonstrated and a risk assessment made. Successful demonstrations where all or a majority of objections are met will reduce risk as development progresses. Unsuccessful demonstrations, those with failures and shortcomings, will increase risk. VSCDP contractors have risk abatement programs which single out risk areas for special attention during development and provide for the introduction of alternatives where the initial technical approach is found to be faulty.

Several factors combine to reduce the risk as the development progresses. These are:

a. Two contractors are developing visual systems based upon different concepts.

b. The visual systems described in the attachments to Appendix B are adequate.

c. Contractors have undertaken risk abatement programs and are considering alternates in high risk areas.

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RISK AREA EVALUATION DURING VISUAL SYSTEM COMPONENT DEVELOPMENT PROGRAM

RISK AREAS	DEMONSTRATIONS/TESTS ON OR BEFORE			
	D/E 1	D/E 2	D/E 3a	D/E 3b
Data Source Subsystem				
High detail object images				
Single	X			
Multiple	X			
Static	X			
Dynamic		X		
High content data base	Partial	X		
Capable of expansion			X	
IR and visual spectrum		X		
Data base interaction				
Targets		X		
Special effects		X		
Helicopter parts		X		
Objects		X		
Target numbers, types and abilities (AH-64 CMS requirements)		Partial	X	
Special features		X		
Ease of data base creation and modification		Partial	X	
Image Delivery Subsystem				
Adequate update rate and capacity		Partial	X	
Other operational requirements		Partial	X	
Scene management to reduce adverse effects of overload or other problems			X	
DTV and FLIR sensor simulation		X		

FIGURE 3.5-1

RISK AREA EVALUATION DURING VISUAL SYSTEM COMPONENT DEVELOPMENT PROGRAM (cont'd)

RISK AREAS	DEMONSTRATIONS/TESTS ON OR BEFORE			
	D/E 1	D/E 2	D/E 3a	D/E 3b
Image Display Subsystem				
Head-eye tracking	Simulated	X	X	
Compatability with IHADSS		Partial	Partial	Partial
Low resolution background wide field of view (WFOV) with high resolution area of interest (AOI) insert				
Reduction of transport delay, swimming and jitter in AOI movement when tracking crewman's eye movement	Partial	X		
Acceptability of achieved transport delay				X
Registration of WFOV and AOI scenes		Preliminary	X	
Blending of AOI and WFOV scenes	Simulated	Preliminary	X	
Resolution		X		
Brightness		X		
Distortion correction				
Spherical screen projection		Partial	X	
Flat surface display		X		
IR and DTV sensor simulation		X		
Multi-magnifications and zoom		X		
VSC Operational Suitability				X

FIGURE 3.5-1 (cont'd)

d. The VSCDP contract provides for timely demonstrations.

e. Five additional visual system developers and manufacturers have stated an interest in developing competing visual systems, and at least one is expected to demonstrate a competing system.

3.6 COMPARISION OF ACQUISITION ALTERNATIVES

This section provides an examination of the advantages and disadvantages associated with the various options that are available for introduction of VSC technology into the SFTS.

3.6.1 Technology

It is useful at this point to compare the technologies that are in contention as visual systems for the SFTS. The competition is between Camera Model Board (CMB) and Computer Generated Imagery (CGI). There are three limitations inherent to CMB/LSIG technology that are not expected to be resolved by future technological advances. First, CMB/LSIG visual systems are mechanical devices that require extreme precision to operate effectively. Consequently, CMB/LSIG technology is subject to an additional maintenance burden not present in solid state Computer Generated Image (CGI) technology. Second, model boards are physically large devices that place limits on the geographical area that can be represented. Presently, they are produced by hand. Any reduction in the size of objects without loss of detail is only feasible by some automated means of production, and by reducing the size of the probe. A scale limit is imposed by the ratio of the probe dimension to the helicopter dimension. If this limit is exceeded, the probe and probe protection system will not allow simulated helicopter flight or taxiing within realistic distances from terrain objects and surfaces. CGI, on the other hand, uses a disk-pack for the physical storage of the data base. Once the CGI data base is developed, multiple copies are easily stored and reproduced. This CGI capability provides the added benefit of allowing a given training device to choose among multiple terrain areas and seasonal conditions. Flexibility of this sort is not anticipated for CMB/LSIG technology. Third, CMB/LSIG technology uses static models. Introduction of moving objects (e.g., targets or weapon effects), requires the integration of CGI with the model board. Achieving this capability in a realistic manner without imposing severe restraints on training scenarios requires a technical sophistication that approaches the full-up CGI itself. It

is possible that some type of hybrid form of CMB/LSIG and CGI could produce systems that obviate these problems. CMB/LSIG technology, by itself, will not.

The primary limitation of CGI technology is that any element of information that is to be present in the output requires finite processing resources to be produced. CGI technology will (with the developed VSC) combine processing techniques and hardware in a manner that is capable of successfully competing with CMB/LSIG image detail. This limitation is minimized further because there is no reason to believe that an upper limit on CGI performance is near.

3.6.2 Cost

The principal conclusion of the cost analysis of the various options for acquisition of VSC technology is that replacement of otherwise adequate visual systems with VSC cannot be justified on a cost savings basis. The investment required is of the same order of magnitude as the visual system related Operating and Support costs. It is, therefore, not feasible to expect operating cost savings to offset the initial cost of purchase and installation.

3.6.3 Risk

The principal factor minimizing risk in the VSCDP is the fact that not only are two companies under contract to deliver products, but that up to five other leading visual technology firms are interested in matching the performance of the contracted for VSC. It appears to be recognized within the industry that a capability comparable to the VSC will be a requirement to remain competitive within the market for military simulators. It is, therefore, a conclusion of this study that there is at this time only a low risk that a VSC-like capability will be available at the time identified in the VSC program. Certain specific features of the VSC must remain at a higher level of risk until they are demonstrated. In particular, the combination of head/eye tracking with an area of interest display faces a technical and user acceptance risk that will be medium to high until the actual demonstration of the capability. Actual unit cost also is at risk at this time, and will remain so until full complexity of integrating all requirements is demonstrated.

3.6.4 Option Analysis

As stated in 3.6.2 above, no offsetting cost advantage is realized by replacement of otherwise adequate visual systems. Such decisions would have to be

justified on the basis of user identification of training requirements beyond those now satisfied. Although this study has identified training capabilities associated with the VSC beyond the capabilities present in other visual systems, the establishment of a requirement for such capabilities is a responsibility of the user community and, as such, is beyond the scope of this study.

The following paragraphs, therefore, consider the various acquisition options in which it is possible to substitute acquisiton of VSC for already planned acquisition of other visual system equipment. Options are addressed by component element of the SFTS.

3.6.4.1 CH-47D FS

It is possible to delay the purchase of visual systems for the forthcoming upgrade of the CH-47D FS until the VSC is available. This would mean approximately two additional years of operation with a TV CMB visual system. In addition, the cost of first integrating the upgrade FS with the CMB and later integrating it with the VSC would be a penalty. The use of the VSC would provide a significant enhancement to training capabilities, allowing a larger latitude in future user requirements.

3.6.4.2 AH-1 FS

It would be possible to delay contract award for production units six through eight to allow a VSC system to be incorporated in place of the scheduled LSIG. This could mean up to a 29 month slip in the RFT date for the simulators. The change over to the CGI visual system would also add engineering cost penalties. In view of the comparable training performance expected from the LSIG and the VSC, little advantage is seen from such an action.

3.6.4.3 UH-60 FS

It is possible to directly substitute VSC into the last eight production units for the UH-60 FS. In view of the significant improvement in training capability that this would offer, little reason can be seen for buying eight of the less capable ATACDIG systems now planned. While RFT requirements will force the use of the ATACDIG in earlier lots of the production contract, purchase of ATACDIGs, once VSC is available should be avoided. Later retrofit of the entire set of UH-60 FS to VSC capability can be accomplished as feasible.

3.6.4.4 AH-64 CMS

Current plan calls for the upgrading of the CMS to the VSC as a P^3I effort when the VSCDP is complete. This course of action is made necessary by the extreme significance attached to the earliest possible RFT for the CMS. The progress of the CMS needs to be monitored so that should a schedule change occur offering the possibility, VSC systems can be substituted for the currently planned for ATACDIG systems.

3.6.4.5 Future Systems

It is a conclusion of this study that future acquisitions of SFTS elements should use VSC technology for visual systems. No reason has been found to continue either an earlier level of CGI or future development of CMB technology. Planning at this time for future acquisitions should be based on VSC visual components. It is recognized, however, that attempts to predict technology generally fall short of the mark. Therefore, it is also concluded that a continuous review of visual system technology be maintained. No reason has been found to indicate any slowing down in the progress currently being acheived.

4.0 COMMONALITY: INSTRUCTIONAL FEATURES, HARDWARE AND SOFTWARE

This section of the report presents the documentation generated as a result of the analyses regarding commonality of instructional features, hardware and software elements.

The background against which this portion of the report was written is provided in the form of a problem statement, summarizing the pros and cons inherent to the issue of commonality. A brief discussion of the methodology of each element utilized to approach this issue is followed by the standardization criteria developed to evaluate the appropriateness of commonality for the instructional features, hardware and software elements of the SFTS.

4.1 STATEMENT OF THE PROBLEM

The SFTS is a family of simulators which perform a number of similar functions. The similarity of many parts of the various training devices is such that the requirements can be considered identical. In many of the cases where requirements do differ, they differ in that one set of requirements is, in fact, a subset of the other. In spite of all this apparent commonality, each member of the SFTS is distinctly different from the other. This is largely a result of the fact that each procurement addressed a unique training requirement. Since each procurement was a separate action, little or no cross system optimization has occurred, and as a result, each system has its own unique set of components. The advantages of commonality where training requirements permit, appear obvious; decreased spare part requirements, savings on the number of personnel and the cost of training instructors and maintenance personnel, potential advantages from quantity buys, reduced design effort for future systems, etc. Some of the disadvantages are not so obvious. Standardization to achieve commonality is only obtained at a price. The price can be described as a commitment to current performance, cost and availability. Standardization is like a garment that purportedly fits all sizes. On some it will be just right, but on others it will be too tight, and on still others it will be too loose. Thus, standardization where different training requirements exist will result in necessary compromises between some elements that are "too loose" and some that are "too tight."

The problem, therefore, that faces the SFTS at this point, is to determine how to gain the advantages of commonality without paying a penalty in the process. It requires not only that candidates for commonality/standardization be identified, but

that plans for how and when to implement standardization be developed. This study is the first step in that process.

4.2 COMMONALITY METHODOLOGY

Although many of the same principles apply to both hardware and software, the methodology for analysis of the two is best addressed separately. In addition, the area of instructional features, which transcends both hardware and software is also a separate consideration.

4.2.1 Instructional Features Commonality Methodology

The review of SFTS instructional features began with an analysis of the procurement specifications and other design documents for the SFTS simulators of interest to the present study. From these documents, and from design reports produced by the SFTS manufacturer, instructional features incorporated into SFTS designs were identified. Each of the simulators at Fort Rucker were then examined to determine the manner in which the instructional feature specification requirements were implemented. Instructors who had used each simulator were questioned concerning perceived advantages and disadvantages of each implementation, and a team member exercised the SFTS simulator to provide further information about operation of instructional features when instructor reports were not clear. Emphases in those analyses and examinations were upon hardware commonalities and differences among SFTS simulators, and perceived advantages and disadvantages of feature implementation with respect to instructional efficiency. For those features unique to the AH-64 CMS, no instructor expereince was available. Reliance in those cases was upon information available from Government and contractor participants in the simluator development effort concerning the projected utility of each instructional feature as it is being implemented.

4.2.2 Hardware Commonality Methodology

The first step in analyzing the potential for commonality within the SFTS hardware was to obtain an inventory of existing SFTS hardware at the component level. This information was obtained from the Link Division of the Singer Corporation, the manufacturer of the SFTS devices. Using this information, analyses were performed to determine what commonality exists on the functional level and on the configuration level. If items are common at the configuration level, then they are

interchangeable. If they are common on the functional level, then they are susceptible of being made interchangeable. It is not expected that many "perfect fits" will be identified, but rather that "near fits" will be discovered.

Once components were identified as potential candidates for standardization they were screened against the standardization criteria (see Section 4.3) developed by the team to determine if standardization would be cost-effective for the candidate. Selected candidates that satisfied the criteria were then evaluated to determine the process by which standardization could be achieved.

The development of the standardization criteria is a key activity of this methodology. The criteria is based on indicators such as maintainability, energy efficiency, and safety/hazzard potential compared to the movement within the supporting technology. If the supporting technology is moving fast enough to offer expected significant improvement in the areas listed above, or if it can offer expected significant cost savings, then standardization is not indicated. If no problems are present in the areas cited, then technology movement is less significant. If technology is not moving with any rapidity, then standardization may be warranted in spite of known problems.

4.2.3 Software Commonality Methodology

Two considerations strongly affect the study of software commonality and standardization for the SFTS. The first consideration is the current process of developing software that adheres to standards for supportability as described in MIL-STD-1644A(TD), Trainer System Software Engineering Requirements. The extent to which this has been accomplished is a major factor in developing candidates for standardization. The second consideration is the DoD move to require future developments to use the Ada language. As part of this study's process, an assessment was made regarding the impact of this directive.

The process used by the team began with the assembly of an inventory of software modules to be used in the AH-64 Combat Mission Simulator currently under development. A listing of these modules is provided in Appendix E. This device is the most complex and comprehensive simulator within the SFTS and is being developed under somewhat more rigorous software documentation requirements than past systems. For this reason it establishes a baseline that can be used to make comparisons with the software presently in use in other members of the SFTS. Because of the quantity of software involved, comparisons were made by a process of selective sampling. Samples were selected in areas where commonality can be

anticipated, and also (as a control) from some areas where differences are expected. Based on analysis of the samples, similarities in the modules were identified and their susceptibility for being made common were assessed.

In addition to similarity, the considerations described above (MIL-STD-1644A (TD) and Ada), were assessed in determining final suitability of candidates for standardization. Based on the results of the standardization screening, the team developed a recommended strategy for implementation of the standardization desired.

4.3 STANDARDIZATION CRITERIA

Standardization criteria for instructional features, hardware and software are discussed in detail in the paragraphs 4.4, 4.5 and 4.6 respectively. In general, standardization criteria are measures that can be used to eliminate candidates that may not be suitable for further analysis. The criteria by themselves cannot qualify a candidate for standardization action. In each case that the criteria indicate that a candidate is a potential subject of standardization activity, further analysis must be made to establish an economically feasible (if such exists) process by which standardization can be accomplished. If no such process can be identified, then the candidate will not be recommended for standardization.

4.4 INSTRUCTIONAL FEATURES

4.4.1 Overview

An efficiently designed simulator is a device whose instructional features permit instructional activities to be conducted with a relative minimum of time and effort. Instructional features are training tools, specifically designed to assist the instructor in controlling and managing the instructional process. Properly used, instructional features can impact both the efficiency and effectiveness of training. Some instructional features are applicable to a wide range of simulators, while others address activities specific to certain types of simulators. The principal factors of concern that distinguish types of simulators and that could influence the design of instructional features are the crew configuration of the aircraft simulated (i.e., single-crewman versus multi-crew), the aircraft mission (e.g., utility or attack), the kinds of training intended (e.g., instrument flight, attack mission, or procedures), and simulator configuration (e.g., whether all crew positions are housed together or are mounted on

separate motion platforms). Figure 4.4.1-1 depicts the instructional features to be discussed and the SFTS in which each is found.

SIMULATOR INSTRUCTIONAL FEATURES FOUND IN SYNTHETIC FLIGHT TRAINING SYSTEM SIMULATORS				
	FLIGHT SIMULATORS			
INSTRUCTIONAL FEATURE	AH-64 CMS	AH-1 FWS	UH-60 FS	CH-47 FS
Record/Playback	X	X	X	X
Hardcopy	X	X	X	X
Manual Freeze	X	X	X	X
Automatic Freeze	X	X	X	X
Parameter Freeze	X	X	X	X
Demonstration	X	X	X	X
Demo Prep	X	X	X	X
Malfunction Simulator	X	X	X	X
Store/Reset	X			
Remote Display	X			
Auto Malfunction Insertion	X			
AMI Exercise Prep	X			
Automatic Flight	X			
Automatic Flight Prep	X			
Target Engage Exercise	X			
Target Engage Exercise Prep	X			

FIGURE 4.4.:-1

4.4.2 Instructional Feature Commonality Considerations

Considerations regarding instructional feature commonality are summarized below based on the analysis conducted in Appendix D. Standardization of instructional feature designs across future SFTS simulators would be a desirable goal from the standpoint of economy of maintenance effort. However, the instructional feature portion of SFTS design is its most rapidly developing and changing portion.

- o Freeze Control

Incorporation of the mushroom type switch to control freeze in the CH-47 FS, AH-1 FWS, and AH-64 CMS would be an improvement and much more functional than the alternate action lighted switches currently being used.

- o Hardcopy

Serious consideration should be given to changing the hardcopy print capability on SFTS production units to provide the instructor with the same capability that currently exists in the AH-64 CMS.

- o Demonstration Preparation

Incorporation of the demonstration preparation capabilities of the AH-64 CMS into existing SFTS simulators would facilitate the development by instructors of more useful and effective demonstrations for use with the simulator.

4.5 HARDWARE

A Hardware component is considered a candidate for standarization if:

a. It performs a function that is common to more than one of the present or future systems of the SFTS; and

b. Predictable near-term technological advance offers no significant improvement in cost, availability, supportability, performance, energy utilzation or safety.

The nomination of a hardware component because it meets the standardization criteria identified above, does not mean that a recommendation is automatically made that steps be taken to replace all other versions of that component. The economics of such actions require further study, and an appropriate means for achieving standardization must be found for each selected candidate. The details of this process are addressed in the following paragraphs.

Identification of major systems used on present SFTS is provided in Figure 4.5-1.

4.5.1 Motion Systems

Cockpit motion and crew seat shaking are provided on all present SFTS and will be requirements for future SFTS development. A common motion system has evolved in the development of present SFTS systems starting with the introduction of the 48-inch, six-degree-of-freedom synergistic system on the CH-47C FS prototype in

SYNTHETIC FLIGHT TRAINING SYSTEMS
MAJOR SYSTEM IDENTIFICATION

MAJOR SYSTEM	SFTS SYSTEMS			
	CH-47C CHINOOK FS CH-47D 2B31	AH-IQ COBRA FS AH-IS COBRA FWS 2B33	UH-60 BLACK HAWK FS 2B38	AH-64 APACHE CMS 2B40
Motion System	Link 48" 6 DOF (Proto) Link 60" 6 DOF Ast (Follow-on)	Link 48" 6 DOF (Proto) Link 60" 6 DOF Ast (Follow-On)	Link 60" 6 DOF Ast	Link 60" 6 DOF Ast
Computational System				
Central Processing Unit	DEC PDP-11/45 (Proto) DEC PDP-11/55 (Follow-on)	DEC PDP-22/55	Perkin-Elmer 8/32 (Proto) Perkin-Elmer 3250 (Follow-on)	Perking-Elmer 3250
CPU Production Years	1972-1981	1972-1981	8/32: 1976- 3250: 1980-	1980-
Number/Device	Proto: 2 Follow-on: 3	Proto: 3 Follow-on: 5	Proto: 6 Follow-on:	Flight: 6 CPU+CAPU Visual: 3 CPU
RAM Memory	Proto: 200K Follow-on:	Proto: 256K Follow:on: 544K	Proto: 256K Follow-on:	Flight: 1400K Visual: 600K
Disc (Quantity x Capacity)	1 x 20 M Words + 1 x 1.2 M Words	1 x 20 M Words + 2 x 1.2 M Words 2 x 14 M Words 5 x 1 M Byte	1 x 300 M Byte 4 x 80 M Byte	Flight: 5 x 300 M Byte Visual: 5 x 300 M Byte
Linkage Technology	"T" Standard TTL (SSI)	"T" Standard TTL (SSI)	SCE Distributed TTL (SSI/MSI)	SCE Distributed TTL (SSI/MSI)
Signal Processing Equipment Technology	Function Chips Hybrid	Function Chips Hybrid	MSI Modular - All Functions on one chip	MSI Modular - All Functions on one chip
Visual System				
Type and Quantity	2B31 Proto: 1 CMB Follow-on: 2 CMB Chin Windows: 2 STG 2B31A: 1 ATACDIG	2B33: 2 CMB 2B33A: 2 LSIG 1 TSU Symbology Gen.	Proto 1: 2 CMB Proto 2: 1 DIG I Follow-on: 1 ATACDIG	1 One-channel ATACDIG 1 Three-channel ATACDIG + Hardware Texture

FIGURE 4.5-1

SYNTHETIC FLIGHT TRAINING SYSTEMS
MAJOR SYSTEM IDENTIFICATION (cont'd)

MAJOR SYSTEM	SFTS SYSTEMS			
	CH-47C CHINOOK FS CH-47D 2B31	AH-IQ COBRA FS AH-IS COBRA FWS 2B33	UH-60 BLACK HAWK FS 2B38	AH-64 APACHE CMS 2B40
Visual System (cont'd)				
Displays	2B31 Proto: 2 WAC CRT Follow-on: 4 WAC CRT (3 Active) 2B31A: 4 WAC CRT Chin Windows: 2 WAC CRT	Pilot: 2 WAC CRT CPG 1 WAC CRT 1 TSU CRT	Proto 1: 3 WAC CRT Proto 2: 4 WAC CRT Follow-on: 4 WAC CRT	Pilot: 3 WAC CRT 1 VDU CRT CPG: 3 WAC CRT TADS 1 HDV
Data Base Creation	2B31A: Link VISGEN		Proto 2: Link Digiti-zing Board Follow-on: Link VISGEN	Link VISGEN
Instructor Station				
Display	Sanders ADS 500 (MSI Components) Interface via PDP 11/05, No Refresh 2 DUS	Proto: Sanders ADS 500 Follow-on: Sanders Graphic 7 (LSI Com-ponents) Interfaces by own O:B, Refresh 2 Displays	Proto: Sanders ADS 500 Follow-on: Sanders Graphic 7 2 DUS	Sanders Graphic 7 2 Displays
Student Station				
Control Loading	Link	Link	Link	McFadden Model 492A
Aural Cues	Link Synthesis Equipment	Link Synthesis Equipment	Link Synthesis Equipment	Link Synthesis Equipment

FIGURE 4.5-1 (Continued)

the mid 1970s. This sytem was updated on the UH-60 FS to the Link-designed 60-inch AST system, also planned for use on the AH-64 CMS and on follow-on production of both the CH-47D FS and the AH-IS FWS. This motion system consists of the following items:

- o Structure/base
- o Self-contained hydraulic power system, including:
  - oo Controls
  - oo Pumps
  - oo Distribution
  - oo Accumulators
  - oo Manifolds
  - oo Filters
  - oo Reservoir
  - oo Water-cooled heat exchanger
- o Actuators (6)
- o Platform
- o Maintenance provisions
- o Seat shaker (separate system sharing some hydraulics)

Technological advances in hydraulics and specific motion system components are not expected to provide significant improvements in cost, availability, supportability, performance, energy utilization or safety over the next six to 12 years.

Except for the platform which will be dimensioned uniquely to accomodate different cockpit configurations, full commonality is being achieved for all present SFTS, except for the UH-I FS, and those under development. Since motion system drive signals are controlled by software to simulate helicopter motion and to provide motion cueing, the common system can be used universally on future SFTS without modification, except as stated, as long as pay load capacity, excursion limits, velocity limits and acceleration limits are not required to be exceeded.

The motion system is an excellent candidate for commonality among all SFTS models. The present common system need only be extended to new SFTS development to achieve commonality. Should components, materials or parts become unavailable due to manufacturer changes, shifts to new models and the like, such items

can be replaced by those meeting the same form, fit and function requirements without materially altering the over all commonality of the system.

4.5.2 Computational System

Multiple minicomputers are used for simulation and training management in all SFTS. The quantity required per trainer has increased from two Honeywell DDP 516s or 716s for the four-cockpit UH-1 FS (1/2 per cockpit) to six Perkin-Elmer 3250s, each with an auxiliary processing unit, for the two-cockpit AH-64 CMS (six processing units per cockpit). One or more additional minicomputer(s) and/or other processing equipment are required for each DIG visual system for those SFTS so equipped. This increase in SFTS computer requirements occurred during a 13-year period from 1969 to 1982. Computer models used on present SFTS and those now under development are summarized as follows:

COMPUTER			USAGE
Manufacturer	**Model**	**Available Dates**	
Honeywell	DDP 516 DDP 716	1966-1974 1073-1979	UH-1 FS completed during the period 1971 -1979.
DEC	PDP 11/45 PDP 11/55	1972-1981 1972-1981	CH-47 FS completed during the period 1977 -1982.
DEC	PDP 11/55	1972 - 1981	AH-IQ FS prototype completed 1978 and AH-IS FWS to be completed during the period 1984 - 1985.
DEC	PDP 11/55 Refurbished		CH-47D to be completed in 1986 and AH-IS FWS to be completed in 1985.
Perkin-Elmer	8/32	1976 -	UH-60 FS prototype completed in 1980.
Perkin-Elmer	3250	1980 -	UH-60 FS and AH-64 CMS to be completed during the period 1985 - 1990.

The above summary shows that commonality was achieved over relatively short time frames by the selection of a common computer model for the CH-47C FS and the AH-IQ FS, and a second common model for the UH-60 FS and the AH-64 CMS. Commonality in the first case is being continued beyond the market availability of new PDP 11/55s by using refurbished models for additional quantities of CH-47D FS and AH-IS FWS, the advantages of commonality being the overriding factor in the selection. Commonality was also a consideration in changing computers from the P-E 8/32 used on the prototype to the P-E 3250 used on production models of the UH-60 FS.

Computer technology is expected to continue its advance at the rapid rate experienced in the late 1960s and 1970s. The emergence and application of Very Large-Scale Integration (VLSI) circuit and other microelectronic developments can provide significant increased performance at reduced cost in such areas as:

- o Increased RAM capacity
- o New computer architecture
- o Parallel as well as serial processing
- o Redundant circuit selection without halt
- o Replacement of software functions by hardware
- o Reduced power requirements
- o Reduced size

The computational system hardware consists of the following units:

- o Central Processing Units (CPU)
- o Auxiliary Processing Units (APU)
- o Input/output units
- o Peripheral devices
- o Interface equipment
- o Microprocessors/firmware devices

Hardware selection generally depends upon the selection of the minicomputer. The selection of computer hardware (common to another SFTS or otherwise) for use in future development cannot be made until conditions affecting the

selection at the time the computer(s) will be needed are known. The advantages of commonality in the selection of SFTS computers for new systems are more important where developments occur close together in time (within three years) and become less important as this time interval increases (over five years), and both computer capabilities and simulation and training requirements change.

Commonality should continue to be a factor in the selection of each SFTS computational system but should not be the overriding consideration in the selection.

4.5.3 Visual Processing Systems

The visual processing system consists of the following subsystems:

- o Data base generation equipment(1)
- o Data base(1)
- o Image generator
- o Displays
- o Maintenace/operator station
- o Structure

NOTE: (1) DIG systems only.

4.5.3.1 Image Generator

Three type image generation systems have been used or are now being developed for SFTS visual systems, CMB, LSIG and DIG. CMB is obsolete and is now being replaced by LSIG and DIG, and LSIG use is not planned beyond the production of the AH-1S FWS. Some commonality has been achieved by the selection of the ATAC DIG for the AH-64 CMS, the UH-60 FS and the CH-47D FS. A synthetic terrain generator (STG) is also used on the CH-47C FS and on the CH-47D FS to generate visual cues for the chin window. There has not been a requirement for chin window displays for other SFTS. Should chin window views be required for future SFTS, it is likely that a real time terrain view can be provided by sharing a visual channel from the DIG system. STG is not a candidate for commonality.

Unique DIG hardware uses much the same technology as reported for computational systems in paragraph 4.5.2 above. The impact of emerging microelectronic technology on visual systems is not expected to produce the rapid escalation of capabilities as is being experienced in computer developments driven by

the large computer industry and highly competitive computer market. The DIG system will include commerical computer and/or microprocessors as well as the unique hardware. The high processing speed, parallel processing, high RAM capacities and other achievements expected from emerging microelectronic technology could greatly increase visual system performance capabilities in the areas of increased data base content, object detail, object interactions, out-the-window fields of view, availability and reduced refresh rates.

However, SFTS visual system development is driven by user needs. The present Government sponsored VSCDP will utilize state-of-the-art technology to develop a visual system which meets all SFTS training requirements. Except for Government supported development, new technology has not been applied to production visual systems at the rate experienced with computers in the highly competitve computer industry. This trend is expected to continue. Thus the drive to apply new microelectronic and other technology to improve visual system capabilities will be greatly reduced once all needs are provided for.

Except for possible changes required to meet future needs, and the replacement of obsolete imbedded computers and other commercial equipment, a common image generator which meets all present needs should be considered for use on SFTS developed over the next ten to fifteen years.

4.5.3.2 Displays and Structure

The wide angle collimated CRT display is used for all present SFTS out-the-window views with CMB, LSIG and DIG image generators. This shows that the display is not tied to a specific image generator type and should be considered for commonality independently. Other display methods such as the VSCDP eye tracked, area of interest projection system are being developed to increase FOVs and to maximize the detail that can be processed by the image generator. These technologically advanced systems offer significant improvement in the performance capability of both the image generator and the display system. Visionics displays either use the operational equipment or are designed to simulate the operational equipment. They are not candidates for commonality among SFTS except where the same visionics system is used on more than one helicopter. The structure must change to accomodate each type cockpit, window and canopy.

Technolgical developments in video image projection, eye tracking, scanning, projection optics and CRT displays are not advancing at a rapid rate. Once a

display system is developed which satisfies all user needs, then this sytem can become common for use on SFTS developed over the next ten to fifteen years. Common visionics displays can be used on SFTS only where common visionics systems are provided on more than one helicopter.

4.5.3.3 Data Base

Portions of the data base (gaming area) developed for the AH-64 CMS are also being provided as part of the data base for both the UH-60 FS and the CH-47D FS. Data base objects and surfaces are interchangeable among like DIG systems, and common items are now being used because of the present high cost of data base creation. However, high technology environmental modeling systems are being developed to greatly reduce this cost and to allow the user to create his own data base. A common date base is not a desirable feature in that different type helicopters require different operating environments.

Data base commonality should be considered among like helicopter types. Partial data base commonality should be considered among unlike helicopter types until the cost of data base creation is substantially reduced.

4.5.3.4 Maintenance/Operator Station and Data Base Generation Equipment

Commonality among maintenance/operator stations and data base generation equipment is determined by the selection of a common image generator system.

4.5.4 Instructor Stations

The instructor station for all SFTS developed to date consists of the following subsystems:

- CRT(s) for alphanumeric and graphic displays*
- Keyboard
- Other controls and indicators
- Layout, workspace, storage area and seat(s)

* Two alphanumeric display CRTs are provided at instructor stations for two-man crew cockpits (CH-47 series FS and UH-60 FS).

- Communication items
- Observer position

A visual display monitor and hard copy device are included in the instructor station of the AH-64 CMS only. Monitoring of student out-the-window scenes on other simulators is accomplished by the instructor actually viewing the student station displays. The hard copy device for the other simulators, though used by the instructor to print CRT displays, is not located at the instructor station.

Common components and designs have been used on present SFTS, except for different specification requirements and changing helicopter capabilities, missions and tactics. Technological advances can occur in commerical equipment used in instructor stations but is not expected to affect overall design.

The instructor station of a simulator is the interface through which an instructor controls the process of instruction for which the simulator was developed. To the extent that the instructional process across SFTS simulators is similar, the design of the interface, i.e., the instructor station, can be similar. In the case of the SFTS, however, there are important differences in the instructional processes applicable to each simulator that precluded a high degree of instructor station design commonality. These differences include the configuration of the aircraft simulated (side-by-side versus tandem crew seating), aircraft mission (utility versus cargo versus attack), and on-board system (e.g., INS, ECM, sensor). It is probable that such differences in future aircraft will be even greater than differences in present Army aircraft.

Design of man-machine interfaces, of which an SFTS instructor station is an example, is a human engineering problem that must take into account operator workloads, division of tasks among operators, anthropometry, and other considerations unique to specific systems. Attempts in the past to standardize interface design where tasks to be performed may differ have not been successful. The Army should not attempt to impose a design on any equipment interface that is not optimum to the equipment/function to be performed with it. In the case of the SFTS, imposing a common instructor station design on future simulators where instructor tasks and workloads are not common would not result in optimum designs. Rather, the design of each simulator or instructor station should be derived though application of human engineering principles for interface design, and an optimum design solution for each new simulator should be sought.

The foregoing not withstanding, commonality of simulator instructor station components, consistent with human engineering principles of interface design, should be sought for reasons summarized elsewhere herein. Candidate components would include CRTs, switches, instructor seats, and communication equipment. There should be no requirement for commonality in the number of such components or their physical placement, however. Such consideration should be resolved through accepted human engineering design practices (e.g., mock-up) as has been done with Army simulator instructor stations in the past.

4.5.5 Student Stations

Student station items can be divided into five groups:

a. Configuration dependent - Actual helicopter parts, or items used to simulate actual helicopter part functions that can be common to one or more SFTS only if the same part or function is used on more than one helicopter type.

b. Common - Items common on present SFTS.

c. Could be common - Items that are not common on present SFTS, but could be common to more than one SFTS.

d. Partially common - functions that can have common items, but also require unique features.

e. Unique - Those items which cannot be common to more than one SFTS model.

The following is a list of student station items divided into the above categories:

- o Configuration dependent
  - oo Instruments and controls
  - oo Communications equipment
  - oo Seats
- o Common
  - oo Out-the-window visual displays
- o Could be common

- oo Motion system warning light and deactivation
- oo Cockpit air conditioning
- oo Single seat shaker for single student cockpit
- oo Dual seat shaker for two-student cockpit
- oo Problem control panel and indicators
- oo Amplifiers and speakers for aural cues
- oo Safety items
- oo Control loading

o Partially common

- oo Aural cue generation

o Unique

- oo Cockpit shell and structure
- oo Canopy and windows
- oo Interior configuration

A standard LINK synthesis method is now used to generate aural cues for each type flight simulator. The creation process starts with the recording and analysis of actual helicopter sounds. The analysis results determine the hardware requirements needed to simulate distinctive helicopter sounds. Uniqueness of the functions required for various sounds require much hardware (i.e., printed circuit cards), and cards are not directly interchangeable among different type simulators. The following is a summary of the quantities of cards used:

SIMULATOR	QUANTITY OF CARDS 4" X 8"	10" X 11"
CH-47 series FS	17	
AH-IS FWS	104	
UH-60 FS		15
AH-64 CMS		32

Sub items of the student station are not subject to high technological mobility. Rather, distinctive functions are required for each type simulator to accomodate the differences among aircraft. In some cases this can be accomplished by an adjustable or programmable common system such as "control loading," which can be used on all simulators. "Common" or "could be common" items are independent of the aircraft and an excellent prospect for commonality among all type simulators. "Configuration dependent" items are subject to commonality only where the same item or configuration is used on two or more aircraft types. Partially common items can be made common only to the degree that the same design can be used to simulate more than one aircraft.

4.5.6 Facilities Interface

The facility has provided the following items, configured to meet the requirements of the approved Trainer Facilities Report for all SFTS installations:

- o Enclosed space with rooms designed for simulator(s), computers, hydraulics, model boards, air compressors, maintenance, service and training areas.
- o Electric power and grounding.
- o Cooling water for cooling hydraulic fluid.
- o Terminal box with master circuit breaker.
- o Air conditioner, heating and ducting, including some outlet arrangements for equipment cooling.
- o Facility lighting.

The SFTS designs provide for interface with the facilities electric power at the facility terminal box and cooling water at the facility water outlet. The main power distribution panel and emergency power off switches are provided with each type simulator. Raised flooring for the computer room has been provided by the SFTS contractor while that for the visual room has been provided by the facility. Installation and all other equipment is provided by the SFTS contractor.

A comparison of the major facilities requirements for the AH-IS FWS (LSIG visual) and AH-64 CMS (ATACDIG visual) is provided in Figure 4.5.6-1. Common facility interface designs have been achieved in part for common systems such as model boards and motion systems. However, plumbing and wiring details have been

FACILITIES REQUIREMENTS FOR TWO-COCKPIT SFTS AH-IS FWS WITH LSIG AND CH-64 CMS WITH ATACDIG

	AH-IS FWS				AH-64 CMS			
	HEIGHT (FT)	AREA (FT^2)	POWER (KVA)	HEAT LOAD (BTU/HR)	HEIGHT (FT)	AREA (FT^2)	POWER (KVA)	HEAT LOAD (BTU/HR)
FLOOR SPACE								
Simulator Room	25	3,120			27	3,234		
Computer Room	10.5	768			10	2,149		
Hydraulic Room (2)	10.5	288			10	384		
Visual Room	31	4,340						
Air Compressors (2`	6	90						
ELECTRIC LOADS								
120/208 V, 3Ø, 60Hz								
Total Less Visual			72				132	
ATACDIG							120	
Visual Electronics			56					
227/480 V, 3Ø, 60HZ								
Total Less Visual			225				204	
Laser			90					
AIR CONDITIONING, HEATING, DUCTING								
(Addition to normal environmental requirement)				484,398				740,600
TOTALS		8,606	443	484,398		5,767	456	740,600

FIGURE 4.5.6-1

altered to adjust to differing building configurations. Commonality can be accomplished to the point of a standard SFTS facility with the increased production of simulators and the use of common systems in their design. To accomplish this, the standard facility design would have to be invoked upon the SFTS contractor. This is directly opposed to the past method of designing the facility to meet the SFTS installation requirements.

4.5.7 Maintenance and Support

Maintenance items such as maintenance intercom equipment, maintenance lighting and computer work table provided with the trainer are common among SFTS. Other maintenance and support items are recommended by the contractor on the Support Equipment List (SEL) or Spare Parts and Special Tools List (RPSTL), and specific items may be selected by the Government from these lists or from other sources. Standardization and the use of a common item is a major consideration in this selection. This equipment includes such items as:

- o Assembly tester.
- o Special maintenance tools and test equipment.
- o Maintenance staging.
- o Lifts and jacks.

Except for distinctive tools and test equipment for model board and DIG system maintenance (such as a high-speed oscilloscope for the DIG I system) maintenance tools and test equipment are generally interchangeable among different type trainers located at Fort Rucker. Other maintenance items such as storage cabinets are furnished by the facility.

Commonality presently being achieved in maintenance and support is expected to be reduced somewhat with the introduction of the LSIG and ATACDIG, each of which will have special maintenance requirements such as built-in test features and special alignment equipment. Standardization in this area has been a major concern, and the equipment selection process will assure the use of common support items where applicable as the use of common assemblies among SFTS increases. Support equipment is not in a highly mobile technological area, and changes are not expected in the next several years.

4.5.8 Cost Implications

Costs associated with each phase of a flight simulator's life cycle may be affected by commonality of hardware among all simulators within the SFTS. Each phase -- Research and Development, Investment, Operating and Support -- is sequentially and individually addressed in the following sections, together with cost implications of hardware commonality. Within each of the three cost phases, specific cost elements that provide opportunities for cost savings are identified and quantified where possible. In addition, items where costs may increase are noted and the implications of each item are included. All costs are shown in thousands of FY84 dollars.

4.5.8.1 Research and Development (R&D)

For future acquisition of simulators, the most significant area of possible cost reduction in the R&D phase is that of design engineering. Design engineering has many facets, including conceptualization of systems and subsystems, actual design of the system/subsystem(s), subsystem(s) integration and testing, component evaluation and selection, continuous checking/testing/revising, and documentation of the results, to name a few.

Using the motion system as an example, it is logical that adoption of a standard design will reduce a significant part of the design engineering effort. The need for evaluation of motion system requirements as they apply to any future simulator would of course remain, so as to assure compliance with the specified gross weight, acceleration velocity and excursion limits of the adopted, standard design. In addition, the engineering effort required to interface and integrate the motion system with the control loading, computational, and facilities subsystems will remain. However, design of the motion system as a functioning entity is eliminated. Specifically, the need for design engineering labor and experimental materials normally invested in conceptualization, subsystem design, documentation, component selection, and brassboard development are precluded. The subsystem is therefore treated, more or less, as a build-to-print item.

Several observations can be made related to the simulator as a whole. First, extension of the ideas of commonality in future simulator developments could theoretically eliminate subsystem design engineering, except where subsystems must be unique to the simulator; e.g., the student station/cockpit area. Second, design engineering required to effect subsystem(s) integration may be reduced, but cannot be

eliminated. Third, reduction in design engineering requirements may result in a reduction in elapsed time required for R&D. Note, however, that simultaneous development may occur among subsystems, and therefore preclude time line extension of R&D.

With a reduction in engineering design and a possible reduction in elapsed time in the R&D phase, several other associated but less significant elements of cost will correspondingly be reduced. System/project management for both the selected contractor and the government's in-house team will decline as the scope and length of effort shrinks. Segments of the technical data package will be available, requiring only minor reformatting and reproduction. In addition, continuation of the standardization process may result in reduced contractor test and evaluation costs.

As related to future acquisition, quantification of cost reductions that may accrue due to commonality can be addressed only in broad terms. No data is available that provides separation of the various activities within the sphere of development engineering. To quantify possible cost reductions, this separation is necessary, as implied by the example of the motion system, where within the development engineering sphere, design of the system is eliminated but design effort for interface and integration is not. Similarly, the reduction in elements of cost associated with a reduction in design engineering cannot be accurately projected. However, the trend of cost reduction can be as shown in Figure 4.5.8.1-1, based on data from the most recent Baseline Cost Estimate for the AH-64 CMS dated 18 November 1982*. Costs are shown in thousands of constant FY 84 dollars.

COST REDUCTION TREND

Subsystem	Total Cost of Design and Prototype Mfg.	Cost of Engineering Development Labor	Percent of Engineering Development to Total Cost	Commonality Status
a. Pilot Trainee Station	$ 1,334	$ 784	59%	Partial
b. Co Pilot Gunner Station	875	484	55	Partial
c. Instructor Station	337	146	39	Candidate
d. Visual System (ATACDIG)	5,225	2,753	53	Candidate
e. Motion System	1,006	71	7	Partially in effect
f. Hardware Integration	1,175	442	38	Candidate
g. Digital Computer System	2,350	101	4	**Partially in effect

* Breakdown of data based on contractor provided detail within the cost proposal.

** Simulators for CH-47 and AH-1 use Digital Equipment model PDP-11. Simulators for UH-60 and AH-64 use Perkin-Elmer Model 32 series.

FIGURE 4.5.8.1-1

The cost savings effect of commonality is already apparent. Using the motion system again as an example, recent simulators (for the AH-1, UH-60 and AH-64) have been or will be produced using the six-degree-of-freedom 60-inch system.

Notice that the engineering development cost represents only 7% of the total design and build prototype cost for the motion system. In addition, the digital computer system procured by the contractor is principally an off-the-shelf standard item, and therefore reflects a very low development engineering percentage (4%). Other subsystems where some commonality would be expected also show development engineering as a lower percent of total cost; viz., the instructor station and integration of subsystems, 39% and 38% respectively.

Additional data are not available in sufficient detail to extend the analysis to a fully serviceable conclusion. However, within PM TRADE, a cost data collection system is currently in place to retrieve data from future proposals and contracts for simulators, sufficient in detail to permit similar analysis. The conclusion that can be drawn is general in nature: Commonality will reduce development engineering costs in the R&D phase of future simulator acquisitions. The reduction may approach 50% for some elements of cost as shown by the difference between student stations and motion system (59% or 55% - 7% ≈ 50%) in the data. Or, the reduction may approximate a lesser amount (20%), as results from the difference between student stations and instructor stations (59% or 55% - 39% ≈20%).ExtendingtheAH-64CMSdevelopment and prototype example to the total estimated costs for the project:

			FY 84 $K
a.	Subtotal Development Engineering Costs (items a + b + d)	=	$ 4,021
	Cost Savings at 50%	=	$ 2,010
b.	Subtotal Development Engineering Costs (items a + b + d)	=	$ 4,021
	Cost Savings at 20%	=	$ 804
c.	Total R&D Phase Cost Estimate (contractor only; i.e., excludes in-house)	=	$46,153
	Savings of $2,010 (item a) represents 4.4% of total R&D.		
d.	Total R&D Phase Cost Estimate	=	$46,153
	Savings at of $804 (item b) represents 1.7% of total R&D.		

A word of caution concerning acquisition strategy and long term effects of commonality is worth repeating at this point. The process of specifying a particular component or subsystem in order to bring about commonality has the effect of reducing competition. A reduction in competition may, in turn, fail to encourage system or design improvements, or may limit the number of potential suppliers. The net result is risk of technology stagnation, or risk of cost increase.

4.5.8.2 Investment

The investment phase of the life cycle provides one significant opportunity for cost savings: Initial spares and repair parts. Other less significant elements of cost that may benefit from commonality include non-recurring tooling, recurring production, system test and evaluation, and data.

With respect to initial spares, a logistics system is in operation that has the capability to quantify the extent of common parts among the various devices. The base data is compiled and is furnished by Singer-Link. All simulators produced to date have been fabricated by that supplier. The Aviation Systems Command (AVSCOM), St. Louis, evaluates the base data to determine initial spares requirements both for components/spares that are new to the spares inventory, and for components/spares common to one or more existing Army simulators and already in the inventory. The assessment of spares requirements includes failure rate analysis for determination of proper stock levels and a comparison of parts numbers against the listing of national stock numbers (NSN). The spares are procured by Singer-Link under the annual maintenance contract which provides not only the means for such activity, but a centralized purchasing function as well. Replenishment spares for all operating simulators are routinely purchased and distributed by this organization. More detail of the organization and functions of the maintenance responsibilities are provided in section 4.5.8.3 below.

Based on the current methods of spares requirements determination and centralized procurement, it may be concluded that some cost benefits accruing due to reduction of initial spares are already being realized. It can further be concluded that the rate of savings in initial spares cost is roughly proportional to the ratio of hardware commonality. As an example, if the cost of the device being produced utilizes common hardware whose cost represents 10% of the total value of the production cost element, then it can be reasonably expected that reduction in cost of initial spares should approximate 10%. However, adding simulators (to the SFTS

inventory) that contain hardware common to existing simulators will increase the minimum/maximum inventory levels of certain spares due simply to the quantity fielded. This will result in a slightly less than 1:1 reduction in initial spares cost. The relationship is illustrated in Figure 4.5.8.2-1. Historically, initial spares have been estimated to cost 10-17% of recurring production cost, as shown by the data in Figure 4.5.8.2-1. Applying the rationale discussed above, cost savings for initial spares at 10% commonality may be expected to approximate the values listed in Figure 4.5.8.2-1. Costs are shown in thousands of constant FY 84 dollars.

Since the factor of 10% added commonality is arbitrary and since the data shown are estimated, it cannot be concluded that $115 savings on each simulator can be realized with each 10% increase of common hardware. However, the trend of proportionality between the percent of common hardware and the percent of reduction in initial spares should result.

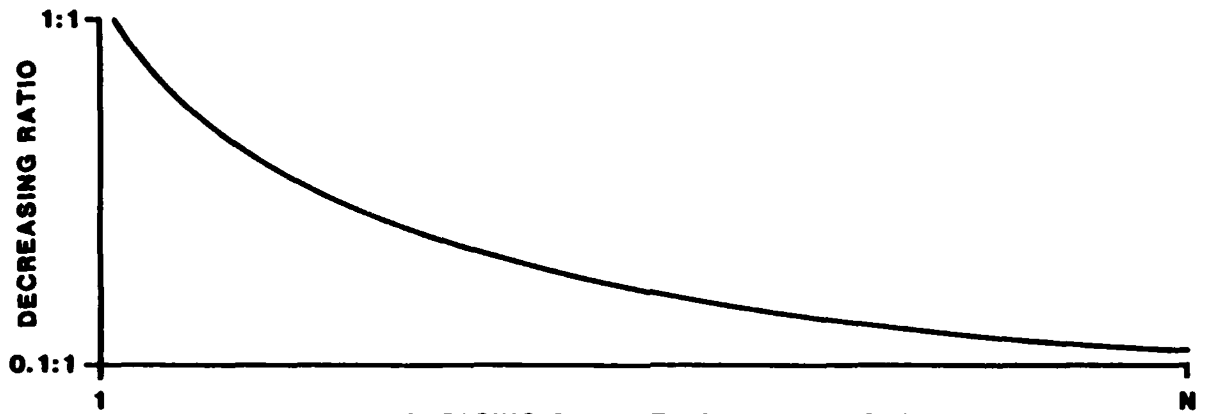
Standardization of hardware will also have an impact on future production quantity acquisitions in related non-hardware areas. For example, non-recurring production tooling requirements may decrease at a rate similar to the standardization ratio. System test and evaluation tests may also decrease if whole subsystems are standardized. The cost of data in the production phase is a less apparent area of cost savings. Certain technical manuals, handbooks, field manuals, etc., for standardized subsystems may require only minor modifications in order to prepare them for publication and distribution.

Recurring production costs may also be reduced due to a learning curve effect. However, cost savings are probably more effected by continuity or breaks in production than by commonality of hardware. In addition, should a supplier other than Singer-Link be selected for future production contract awards, the entire simulator would represent "nonstandard, noncommon" hardware to that selected manufacturer. In any event, the costs related to learning will probably not be significantly or measureably affected by the existence of common hardware.

4.5.8.3 Operating and Support (O&S)

The final phase of the life cycle, O&S, represents the period during which the most significant savings can be realized from commonality of hardware. The potential for savings is magnified by the fact that operations generally extend over a 20 year period.

INITIAL SPARE COST VERSUS QUANTITY



SYSTEM	QTY OF SIMULATORS	RECURRING PRODUCTION COST OF SIMULATORS	ESTIMATED COST OF INITIAL SPARES	TOTAL COST SAVINGS AT AT 10% COMMONALITY*	SAVINGS PER SIMULATOR* AT 10% COMMONALITY
CH-47D	2	$ 19,178	$3,331	$ 333	$ 167
AH-IS	8	87,279	8,728	856***	107
UH-60**	8	61,270	6,127	601***	75
AH-64 CMS**	4	60,821	7,299	730	183

* Approximate cost savings with an increased level of common hardware of 10% above the current level of commonality.

** Includes the ATACDIG visual system.

*** Assumes a slight reduction of 2% in the savings ratio, with higher quantities deployed.

Mean savings per simulator = ($333 + $856 + $601 + $730) ÷ (2 + 8 + 8 + 4) = $115 at 10% commonality.

FIGURE 4.5.8.2-1

Operating costs result from many variables: Number of instructors, hours of operation, power requirements, spare requirements, reliability of equipment, maturity of the aircraft being simulated, site of the simulator, and maintenance requirements (during operation and off-hours preventive maintenance). Maintenance costs include two principal elements, labor and replenishment spares. The maintenance of all Army simulators is 100% contractor support.

A review of estimated operating costs reveals that contractor maintenance represents the largest share of total operating costs. Costs are shown in thousands of FY 84 constant dollars.

OPERATING COST FOR SIMULATOR PER YEAR

		SYSTEM			
	ELEMENT OF COST	CH-47	AH-1	UH-60	AH-64
1.	Contractor Maintenance*	$ 518	$1,041	$ 644	$1,091
2.	Instructor Pay & Allowances	96	127	115	184
3.	Electrical Power (Device & Bldg.)	154	232	131	220
4.	All Other Operating Costs**	260	154	84	296
	TOTAL	$1,028	$1,554	$ 974	$1,791

* Includes contractor maintenance labor and replenishment spares and materials.

** Includes costs for modifications, facilities maintenance, and the indirect costs related to instructor personnel (medical support, quarters maintenance and utilities, replacement, etc.).

With respect to the labor related component of maintenance, one contractor currently provides this service to all Army SFTS devices. The major portion of this effort is located at Fort Rucker where the largest concentration of devices is found.

Organization of this function is shown in Figure 4.5.8.3-1.

Staffing is as follows:

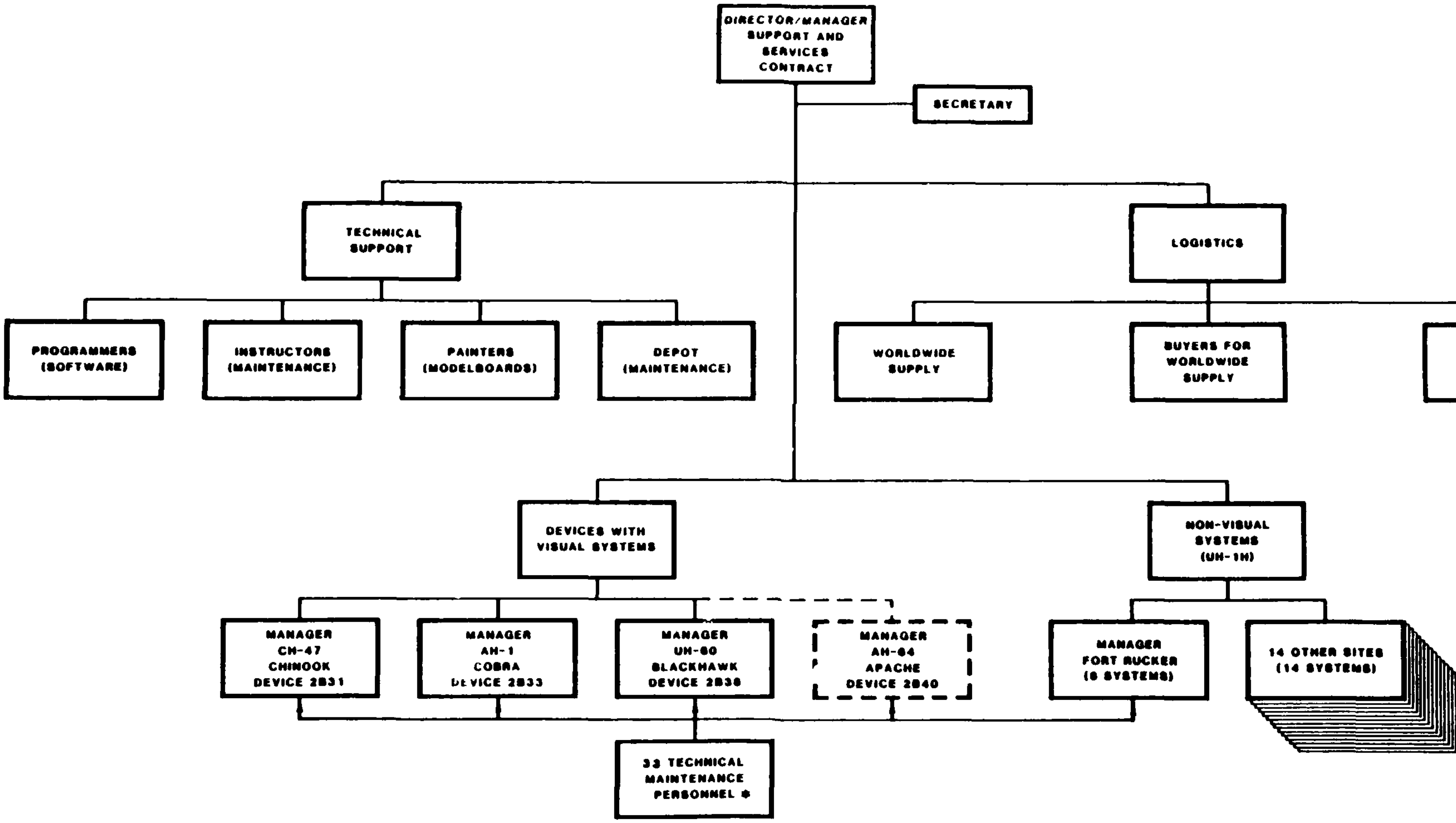
GROUP	TOTAL	NUMBER VISUAL* SUBSYSTEM DEVICES	NON-VISUAL* SUBSYSTEM DEVICES	OFF-SITE* DEVICES
Technical Support	21	10	8	3
Logistics Worldwide	17	8	6	3
Maintenance	83	38	31	4**
Contract Management	2	1	1	--
TOTAL	123	57	46	20

* Split according to maintenance personnel ratio of visual/non-visual simula...s.

** Includes only maintenance operation supervisor for 14 sites. Other technical maintenance operators at each of the 14 other sites are not included.

The following discussion addresses the maintenance contract personnel that support the simulators with visual subsystems. Cost savings that accrue in the technical support and logistics worldwide areas due to commonality may be generally comparable to the reduction in types of components and parts. For example, procurement actions for small quantities of parts are as costly as those for large quantities. A reduction in the number of different spare line items will therefore result in reduced procurement actions. This phenomonon is important when consideration is given to the planned, future expansion of the SFTS, and may serve to prevent growth in labor costs of the logistics function.

The number of maintenance personnel may be reduced by elimination of skill categories. For example, with the replacement of model board technology by some other technology, the unique skill of model board painters could be eliminated. Similarly, existence of common hardware may permit reduction in technical maintenance areas. Maintenance operators will become more efficient in repair or replacement tasks, if the variety of equipment is reduced. Using the model board painting operation as an example (there are currently three artists), the Government may expect to save 1.8 million ($30 thousand per person per year) over 20 years operation with deletion of that skill requirement.



* POOLED, NOT DIRECTLY ASSIGNABLE BY PROGRAM

FIGURE 4.5.8.3-1 CONTRACTOR MAINTENANCE ORGANIZATION FOR SFTS

Other normal elements of cost in the O&S phase offer no significant savings potential. The elements include the instructors' pay and allowances, military operated depot facilities (non-existent), electrical power consumption, modifications, facilities maintenance, and consumables (other than replenishment spares). The cost of these elements are driven by factors other than common hardware.

4.6 SOFTWARE

Software commonality is a function of a number of factors. These factors can be categorized as current/anticipated DoD and service component software policies, similarity of future SFTS software requirements (i.e., considering the existing or "in process" trainer, standard software methodologies and practices, standard Programming Support Environments (PSE) and standard High Order Language (HOL)). Other factors to consider would be the procedures and facilities for the maintenance and configuration control of standard modules across systems (e.g., a standard module library and control capability).

More that 685 modules (see Appendix E) of software have already been identified for the AH-64 CMS. The design effort is still continuing, and the modules reported to date do not include any of the software related to the visual system. In any case, if 100 lines of source code are assumed per module, it can be expected that the AH-64 CMS will end up with well over 100,000 lines of source code. (Informal estimates by the developer place this number as high as 300,000.)

The CH-47C FS has 146,000 lines of assembly language code in the production version. The AH-1 FS prototype has 178,000 lines of assembly language code. The number of source lines for the UH-60 FS are not available, but an estimate of 70,000 lines of FORTRAN and assembly language code is probably conservative.
These four simulators alone generate an inventory of almost 500,000 lines of code for the World Wide Software Support Center to maintain. Edmund Daley (1) has indicated that a full time programmer can maintain about 10,000 lines of real-time software. Using Daley's figure, it would require about 50 programmers along with testers, people performing configuration management, etc., to support these four devices throughout their life cycle.

(1) Daley, Edmund B.; MANAGEMENT OF SOFTWARE DEVELOMENT, IEEE Transactions on Software Engineering, May 1977, page 232.

FORTRAN generally replaces assembly language at a ratio of 1 line of FORTRAN for 4-6 lines of assembly language. Thus, conversion to FORTAN alone would reduce the inventory to be maintained to about 235,000 lines of code. If, in addition, 50% of the code in each system is common to all systems, then the inventory is further reduced to about 170,000 lines. Such an inventory would require 17 programmers for a net savings of 33 man years per year. If a man year costs the government $50,000 (including all overhead) then the annual savings would be $1,650,000 and, over 20 years, $33,000,000.

Another approach to obtaining a rough estimate of the potential savings that could result from common SFTS software is based on the fact that DoD experience shows that 70% of the life cycle costs associated with software occur post deployment. In addition, DoD experience shows that the development cost per line of code ranges from $50 per line to over $350 per line. If the low figure is used, then the estimated 500,000 lines of unique code will cost 2.333* X 50 X 500,000 = $58,325,000 for post deployment support. If the quantity of unique code is reduced to 175,000 lines, then the associated post deployment support costs would be reduced to $20,413,750 -- a savings of almost $38,000,000 over the life cycle.

All of the figures used above are subject to individual challenge. None of them are advanced as firm data. They do, however, serve to illustrate that software commonality can offer significant cost savings over the life of the SFTS. When such savings are coupled with the savings that could be obtained in future acquisitions as well, then the reasons for pursuing software commonality become self evident.

The principal considerations relating to the standarization of software within the SFTS are as follows:

a. What software is currently present?

b. What commonality exists or can be made to exist?

c. What is the maintainability of the potentially common software?

d. What is the transportability of the potentially common software?

e. What impact will emerging DoD standards such as Ada have on SFTS software?

The following paragraphs address these considerations and present the team's conclusions with regard to software standardization.

* (70% post deployment) + 30 % pre-deployment = 2.333 factor.

4.6.1 Existing SFTS Software

Based on data collected from Singer-Link and from the World Wide Software Support Center at Fort Rucker, Figure 4.6.1-1 has been constructed to present the current status of SFTS software.

CURRENT STATUS OF SFTS SOFTWARE

DEVICE	PROTOTYPE RFT	COMPUTER	LANGUAGE	STATUS
2B24 UH-1	March 71	Honeywell 516,517	Assembly	Production complete Upgrade in planning
2B31 CH-47	January 77	DEC PDP 11/45	Assembly	Production ongoing
2B33 AH-1	December 78	DEC PDP 11/55	Assembly	Production ongoing
2B38 UH-60	April 80	PERKIN-ELMER 8/32, 3250	Assembly & FORTRAN	Production pending?
2B40 AH-64	---	PERKIN-ELMER 3250 wAPU	FORTRAN & Assembly	In development

FIGURE 4.6.1-1

As shown by Figure 4.6.1-1, the early flight simulators were developed using assembly language on Honeywell and DEC machines. With the 2B38, the move to FORTRAN was begun and the computer was shifted to Perkin-Elmer. In the 2B40, which is now being designed, the use of FORTRAN is being extended and the Perkin-Elmer computers are being continued. In addition, under the production contract now being negotiated for the 2B38, considerable engineering effort is being contemplated for the software to bring it in line with the requirements of MIL-STD-1644A (TD). That same standard has been imposed on significant portions of the software being developed for the AH-64 CMS.

4.6.2 Current Commonality

Assembly language is a lower order programming language. That is, it works directly with the instruction set architecture of a particular computer. For this reason, assembly language programs are physically different for different computers even if the functions performed are identical. FORTRAN is a higher order language (HOL) which uses a compiler to translate its instructions to those of a given machine. However, because FORTRAN was developed early in the evolution of computers, it is not identical for all machines. For this reason, two functionally identical programs written in FORTRAN for two different machines will not necessarily be the same.

Of the software delivered to date for the SFTS, only one system (i.e., UH-60 FS) is programmed in FORTRAN. The others are programmed in assembly language for different machines. For that reason, the software that exists today for each individual system is totally unique for that particular system even though many of the functions performed are identical or nearly identical across all systems.

In addition, because FORTRAN offers many variant ways of programming any particular function, there is no reason to believe that the FORTRAN code to be delivered to the AH-64 CMS (2B40), will be identical to that for the 2B38 except where it proved expeditious and convenient for the developer to make it so.

The bottom line is that physical commonality does not exist for SFTS software today. Analysis of the software at the functional level indicates that strong functional similarity does exist. A listing of the 2B40 non-visual software modules was examined with the help of World Wide Software Support Center personnel to estimate the functional commonality that does exist. The results of the comparison are at Appendix E. The comparison shows that functional similarity exists across better than 65% of the known 2B40 modules. Wherever such similarity has been identified, a strong potential for establishment of physically common software exists.

4.6.3 Software M[illegible]ability

Software [illegible]bility can be defined as the ease with which problems can be diagnosed and [illegible]r modifications can be installed and validated within a given program.

A program that scores low in "maintainability" is one in which it is more feasible to throw the code away and start over from scratch rather than attempt to modify it or correct it. One that scores high in maintainability is one that can be

easily modified or corrected with little or no question about the resulting effects of the change.

MIL-STD-1644A(TD), Trainer System Software Engineering Requirements, has been established by the Naval Training Equipment Center as a standard to achieve maintainability features in software. The requirements of MIL-STD-1644A(TD) have been partially imposed on the AH-64 CMS software. A move is currently underway to bring the UH-60 FS software to the same standard.

The degree to which either of these actions will succeed remains to be evaluated, however, it is a highly desirable direction in which to be moving. It is a conclusion of this study, that the potential advantages of such "maintainability" requirements as are contained in MIL-STD-1644A (TD) are so significant that software that does not meet such requirements should not be considered for standardization without first being brought into conformance with such requirements.

4.6.4 Software Transportability

Transportability, as applied to software, is the capability of a software package to be moved from one computer to another. Transportability is a highly desireable attribute for software, particularly because computer hardware technology is moving very rapidly. FORTRAN achieves a higher level of transportability than assembly language, however, FORTRAN is still so tied to a particular machine that some conversion process is almost always needed when changing computers. The next generation of higher order languages, such as Ada, are intended to provide an increased degree of machine independence such that transportability will be greatly enhanced. Some adjustments will be needed to accomodate new performance capabilities to new hardware, however, most software modules coded in Ada will not require recoding to move to a new computer.

4.6.5 Common Data

Real time software performs simulation by updating items of data that describe the object of the simulation. These data items are used by other parts of the software to perform calculations, to drive displays, to control the motion system, to provide instrument readings, etc. The rate at which data items are updated can vary from once a second to 60 times per second. In a flight simulator such variables or data items represent all the instantaneous data about the aircraft such as control settings, stick positions, acceleration vectors, velocity vectors, etc. In fact, in a flight

simulator, the set of variables that describe the simulation's dynamic status will be numbered in the thousands. In addition, the entire fixed environment in which the simulated aircraft is operating must also be described. In a computer visual system, each tree, each building, each road, each target, each river, each hill must be represented by a set of data items that serve to describe it in sufficient detail to allow not only its visual representation, but also its interaction with the simulated aircraft to be accomplished.

Data management is a major task, both during development and post deployment. However, because the various flight simulators have been developed on different computers at different times, no real alignment of the data from one trainer to another exists. If the software is to be common across trainers, then the data will also have to be common across trainers. While differences in vehicles being simulated and differences in design of the simulators will prevent a total common set of data items, a significant number should be susceptible to normalization. In addition, clear documentation of the differences in data among trainers will be a major aid in increasing productivity in the software support facility.

4.6.6 Effect of Ada* and Other Dod Actions

The DoD and service component directives and guidelines which govern the management and use of computer resources have been constantly under revision in recent years. DoD Directive 5000.29, "Management of Computer Resources in Major Defense Systems" is being revised. DoD MIL-STD-480, Configuration Control - Engineering Changes, Deviations and Waivers, 483 Configuration Management Practices for Systems, Equipments, Munitions and Computer Programs, and 1679 Weapon System Software Development will be affected by a new draft DoD MIL-STD-SDS, Defense System Software Development (Draft). This in turn will affect MIL-STD-1644A(TD). This standard, which is the primary requirements document for trainer system software development, is also in the process of revision (draft MIL-STD-1644B). DoDInstruction 5000.31, "Interim List of DoD Approved High Order Programming Languages" has been superceded by a draft DoD Directive 3405.1. The AR 70-XX on procedures for acquisition of mission critical computer resources is still to be published, although several drafts have been circulated. This constant state of

*Ada is a registered trade mark of the Department of Defense Weapon System Software Development (Ada Joint Programs Office) OUSDRE (R&AT).

change is indicative of the turmoil still underway in specifying standards and guidelines for the acquisition of computer resources, in general, and software, in particular.

One program that is causing many of the above policy changes is the DoD Ada Program. The provisions of the interim DoD policy on computer programming languages will have a major effect on the SFTS . This policy was issued by Dr. DeLauer, Under Secretary of Defense for Research and Engineering, on 10 June 1983. Its essence is as follows:

> "The Ada programming language shall become the single, common, computer programming language for Defense mission-critical applications. Effective January 1, 1984 for new programs entering Advanced Development and July 1, 1984 entering Full-Scale Engineering Development, Ada shall be the programming language. Only compilers which have been validated by the Ada Joint Program Office shall be used for software to be delivered to or maintained by the government."

The Ada policy has several facets with regard to the SFTS. First, this policy is not retroactive. Those trainers which are in operation or in production or for which a computer programming language commitment has been made will not be required to change to Ada. Thus, the trainers for the UH-1H, CH-47, AH-1S, UH-60 and AH-64 should not be affected. However, future trainer programs such as those for the OH-58D, LHX and SATT will fall under the purview of this policy. Also, if there were any major modifications to the software for existing trainers which would entail a significant conversion or redesign effort, then the provisions of this policy may apply.

Apart from this policy and the mechanics of its implementation, there are several key questions. They are: "Will Ada significantly improve the capability to develop SFTS software? If so, will it aid in the achievement of a viable software commonality for SFTS?" Put in another way the question might be: "If there were no policy that requires the use of Ada, would it be the best choice anyway?" Specific factors to consider about the acceptability of Ada are: Applicability to SFTS software, standardization status, availability/maturity, capability of integration with existing software and portability.

Ada was designed for realtime, embedded systems such as those in the SFTS. It was built for realtime control and parallel processing. It should obviate using any assembly language and consequently improve software portability. Its use leads to

the development of reliable and maintainable software. It is intended for large software systems that can be easily modified.

Actual use of Ada has been very limited. Only three translators have been validated to date (see Figure 4.6.6-1). However, as the availability of compilers and Minimum Ada Programming Support Environments (MAPSE's) have increased (see Figure 4.6.6-2), as more personnel become trained, as more requirements for the use of Ada surface, user experience and feedback on Ada will increase. Ada technical organizations such as Ada Technical Committee and users groups such as Ada JOVIAL User's Group (JUG) aid in this regard. Ada is being used in the commercial world. Intellimac, Inc. has built and is marketing several business applications programs done in Ada. Ada is appearing as a requirement in DoD RFP's now.

Any transition to Ada should be based on a reasonable strategy. Any projects that either were required to use Ada or desired to use Ada now could use it as a Program Design Language (PDL). As the project progressed and it became apparent that appropriate compilers were available, Ada could be used as the implementation language. At the same time the use of an Ada Programming Support Environment (APSE) could be phased in. Initially, an appropriate Minimum APSE could be used and other tools could be phased in when they were available (given that they were needed). For the SFTS it would appear that the development schedules for the OH-58D, LHX and SATT are such that Ada should be mature as an implementation language.

4.6.7 Software Conclusions

The following conclusions are drawn based on the data and discussion presented above:

a. Significant functional similarity has been identified within the current and forthcoming SFTS software offering an opportunity for arriving at common software.

b. Potential savings on the order of $30,000,000 could be realized over a twenty year period if maximum software commonality is obtained.

c. Software that is to be considered for standardization must meet standards of maintainability, reliability and tranportability.

d. Although software being developed for AH-64 CMS or for the production UH-60 FS may meet the conditions for standardization, none of the software now in the Government inventory should be considered for standardization without modifications to bring it into conformance with standards.

Ada/APSE IMPLEMENTATIONS

VALIDATED

ORGANIZATION	SCOPE	HOST SYSTEM	TARGET SYSTEM	AVAILABILITY
New York University	Interpreter and Operational Definition	Vax (VMS and UNIX) IBM (CMS, MVS, VS1) AMDAHL (UTS)	Same	Now (Validated 3/83)
Rolm/Data General	Compiler and Ada Development Environment	ROLM MSE 800 DG MV 4000, 6000, 8000, 10,000 Series	Same	Now (Validated 6/83)
Western Digital (Gensoft Corp)	Compiler and PSE	WD 1600 Series	Same	Now (Validated 8/83)

FIGURE 4.6.6-1

Ada/APSE IMPLEMENTATIONS
IN-PROCESS

ORGANIZATION	SCOPE	HOST SYSTEM	TARGET SYSTEM	AVAILABILITY
Carnegie-Mellon University	Compiler & PSE	VAX-11 (UNIX) PERQ	Same	1984
Control Data Corporation	Compiler & PSE	CDC CYBER-170	Same	1986
Digicomp Research Corporation	Compiler	Delphi 100	Same	NOV 1983
Florida State University	Compiler	CDC CYBER(NOS)	ZILOG-Z-8000 Development Module, MIL-STD-1750A	DEC 1983
Intel Corporation	Compiler & PSE	VAX (UNIX & VMS)	Intel IAPX-432 IAPX-86	1983 Mid 1984
Intermetrics, Inc. (Air Force AIE)	Compiler & PSE	IBM 370, PE 8/32	SAME	NOV 1984
Irvine Computer	Compiler	VAX AMDHAL, IBM 370 SEL	Same z-8000	1984
Softech, Inc. (Army ALS)	Compiler & PSE	VAX 11/780 (VMS)	Same INTEL 8086 MCF	JUL 1984 SEP 1984 DEC 1985
Telesoft, Inc.	Compiler	VAX (VMS, UNIX) IBM (MVS/TSO, CMS) IBM PC 68000 (UNIX, ROS)	Same 6800 bare machine	JAN 1984
Perkin Elmer	Compiler	PE 3200 Series	Same	Late 1984

FIGURE 4.6.6-2

e. Commonality will not be achieved without a specific program to plan for and acquire common software.

f. The potential benefits of Ada and the successful qualification of compilers for Ada indicate that use of the Ada language should play a major role in any SFTS common software initiative.

g. A move to obtain common software witin the SFTS is in allignment with DoD policy concerned with the reduction of post deployment software supports costs.

h. A significant element of commonality is the data used in the simulation. To achieve software commonality, data commonality must also be addressed.

5.0 RECOMMENDATIONS

Recommendations resulting from the study are grouped in paragraphs corresponding to the major divisions of the study.

5.1 RECOMMENDATIONS CONCERNING VISUAL TECHNOLOGY APPLICATION

It is recommended that the Army standardize the Computer Generated Imagery technical approach currently under development in the Visual System Component Development Program for visual system applications within the SFTS. At the earliest opportunity that does not impose unacceptable delay on Ready-For-Training dates, acquisition of visual systems should be shifted to VSCDP level CGI technology. Current CGI technology cannot support the emerging training requirements for devices such as the AH-64 CMS. Camera Model Boards are both cumbersome to maintain, and are not able to provide sufficient interaction (weapon effects, target motion, line of site determination, etc.) without expensive computer modeling of the same level required for CGI. Therefore, the emerging performance requirements for Combat Mission Simulators has exceeded the capabilities of foreseeable model board technology.

While it is recommended that the Army standardize the VSCDP technology, it is not anticipated that a particular piece of hardware will, in fact, become standard for all simulators. It is recommended therefore, that early action be taken to develop modular capabilities that will allow VSCDP level equipment to be tailored to particular simulator requirements. For example, the display requirements for a cockpit where two students sit side by side are not the same as for a single student cockpit. Visionics simulation requirements will continue to change. In addition, the rate of change in electronics technology that has so drastically impacted computer performance and cost will also affect CGI technology. Therefore, plans for VSCDP utilization must allow for continued maturation of hardware configuration.

The results of this study show that replacement of existing, otherwise satisfactory simulator visual systems with VSC must be justified on the basis of new requirements as the data available for this study does not indicate cost savings when VSC is substituted to meet currently stated requirements.

5.2 RECOMMENDATIONS CONCERNING SYSTEM COMMONALITY

5.2.1 Instructional Features Commonality Recommendations

It is recommended that a program be initiated that will lead to an eventual standardized set of instructional features. A program of structured training effectiveness/human engineering evaluation of instructional features and the controls that implement them is necessary. In recognition of the evolutionary nature in their design in the SFTS, the program should begin with evalution of the new and modified features that are being implemented on the AH-64 CMS. Although it is recognized that time on the simulators is difficult to obtain, the team considers it vital that an evaluation be performed on the simulators as part of the program to develop standardized instructional features.

This set of instructional features should then serve as a library of standard capabilities from which new SFTS components would draw on to satisfy user identified training requirements. Such action will aid the developer by reducing risk and cost in new developments, it will aid the maintainer by reducing the unique software he is required to maintain, and it will help the user by providing well known and documented training capabilities for specification of future requirements.

5.2.2 Hardware Commonality Recommendations

The following recommendations are made with respect to hardware standardization and commonality. It is recommended that:

a. Action be taken to standardize the present motion base hardware. A high degree of commonality now exists within the SFTS. That commonality should be maintained and extended. The steps to be taken include the assembly of a Technical Data Package that adequately describes the motion system such that actions can be taken to second source the system. Policy needs to be stated such that future procurements for the SFTS will use the standard system unless waivers are granted based on reasons not seen at this time.

b. Computational systems not be subject to standardization actions. Computer technology is moving too rapidly at this time to allow selection of any one model or even any one vendor as a standard that can be considered viable for the next several years. The disadvantages of not standardizing computer hardware will be somewhat offset by the emergence of Ada which will provide a greatly improved capability to move software between different computers.

c. Visual system standardization be approached as recommended in 5.1 above.

d. A program for standardization of instructor station components be initiated. The program should be closely coordinated with the program for instructional features standardization recommended in 5.2.1 above. Modularity must be emphasized, such that the tailoring required to suit each aircraft being simulated can be readily accomplished. Because of the high mobility in current display technology, standardization of display elements should be at the form and function level, so that new commercial display equipment can be utilized when it is advantageous to do so. As standards emerge, they should be the basis of future SFTS acquisitions and should be considered during any retrofit of existing SFTS simulators.

e. Further study be made of candidates for standardization at the component level within the student station. The student station by its very nature must conform to the aircraft being simulated and is not, therefore, a candidate for standardization at the subsystem level. The study indicated that some such component level standardization is possible, such as motion system warning light and deactivation, cockpit air conditioning, single or dual seat shaker as applicable, problem control panel and indicator, amplifiers and speakers, safety items, control loading and aural cue generation. Detailed examination of such actions was beyond the scope of this study, therefore, firm conclusions are not warranted.

f. Efforts be continued to assure that standard tools and test equipment be utilized in support of the SFTS to the maximum extent possible. Acquisition of such support items should be approached on a support facility basis, i.e., tools and test equipment should be purchased against the total SFTS maintenance requirement, not on a simulator by simulator basis.

5.2.3 Software Commonality Recommendations

The following recommendations are made with respect to software commonality within the SFTS. It is recommended that:

a. A statement of policy be generated and issued by PM TRADE endorsing the use of Ada on all future flight simulators and simulator upgrades, and indicating that the SFTS is to be managed as a system rather than on the component trainer level. The policy statement should further state that SFTS software/data commonality is a high priority goal for all future SFTS acquisition actions.

b. Immediate steps be taken to determine what degree of commonality can be required between the AH-64 CMS and the UH-60 FS within the scope of current contract activities.

c. Action be taken to develop an SFTS Data Element Dictionary. The dictionary should be automated using the tools available at the World Wide Software Support Center with enhancements as necessary. (This includes those support tools to be delivered with the 2B40 and 2B38.) Enhancements should include all features needed to make the dictionary capable of supporting Ada.

d. Planning action begin to develop a plan for integrating all members of the SFTS into an Ada based common software environment. This plan should be developed not only to improve the cost of maintaining the SFTS, but also to improve the acquisition process for new or upgraded simulators by providing validated software components for a significant portion of the development requirement.

APPENDIX A

SYNTHETIC FLIGHT TRAINING SYSTEM (SFTS) DESCRIPTION

1.0 BACKGROUND

The conventional method of performing helicopter flight and combat training by an instructor pilot in an actual aircraft is costly in terms of student and instructor time on the flight line and in flying hours and ammunition costs. These costs increased significantly in the mid and late 1960's when the Army expanded its helicopter fleet and the number of new rotarary wing aviators graduated each year increased tenfold. At the same time, there was an enlightened recognition of the requirements for better training in emergency procedures and instrument training to avoid accidents and accomplish aviation missions more effectively. The huge increase in the cost of aviation training which accompanied this period of expansion, emphasized the need for an economical synthetic flight trainer which would reduce the requirement for use of operational helicopters for flight training.

To fulfill this need, the Army approved a Qualitative Materiel Requirement (QMR) for development of a Synthetic Flight Training System (SFTS) in 1967. (This requirement document was retitled Training Device Requirement (TDR) Number 0027 in 1975; and was last revised 6 August 1981.)

The SFTS is a family of training devices used to teach flight and other performance skills in utility, cargo, and attack helicopter operation. The first of the family is the UH-1H Huey Helicopter Flight Simulator, Device 2B24, developed in the early 1970's with delivery of 22 simulators (each containing four simulated student stations for a total of 88 stations) during the years 1971 to 1978. These trainers are now in use at various sites in CONUS, Europe and Korea. Each student station is mounted on a five-degree-of-freedom motion platform. The digital computer and two-position instructor station complete the system. There is no visual system with this early model SFTS. Training is provided in those skills not requiring an out-the-window or other visual view, such as: Instrument flight training, navigation, operation with malfunctions and under other emergency conditions and communications.

TDR Number 0027, as revised, established requirements for the following SFTS which are in various stages of development, production and operation:

CH-47 CHINOOK Helicopter Flight Simulator, Device 2B31

AH-1S COBRA Helicopter Flight and Weapons Simulator, Device 2B33

UH-60 BLACK HAWK Helicopter Flight Simulator, Device 2B38

AH-64 APACHE Helicopter Combat Mission Simulator, Device 2B40.

Expected future requirements include SFTS for the LHX Helicopter in both the SCAT (Scout and Attack) and UTILITY versions. The LHX program is presently undergoing concept formulation with production planned to start in the early 1990s. In addition, the requirement for the SATT (Scout Attack Team Trainer) requiring interacting scout and attack helicopter cockpit student stations is being considered.

2.0 SFTS DESCRIPTIONS

Each type SFTS consists of the following major assemblies:

a. One or more simulated cockpit trainee stations.

b. One or more instructor/operator stations.

c. One or more motion systems, each with six-degree-of-freedom (pitch, roll, yaw, and vertical, lateral and longitudinal displacement -except for the UH-1H FS motion system which does not provide longitudinal displacement).

d. Digital computer system.

e. Visual system, except for the UH-1H FS.

Cockpit Trainee Station

The cockpit trainee stations accurately represent the pilot and copilot stations of the actual aircraft. All control and indicator functions required for training are simulated.

Instructor Stations

The instructor stations are located to the rear of the trainee stations, and both stations are located on the same motion system platform. The flight instructor is positioned to obtain an unobstructed view of the trainee and visual displays while having easy access to instructor station controls, indicators and displays.

Motion System

The motion system provides computer controlled acceleration cues experienced in normal and emergency flight maneuvers. Platform motion is programmed to impart most motion cues which crews will experience in an actual aircraft, reinforcing the readings of simulated instruments and the motion being perceived from viewing the visual displays.

Digital Computer System

The digital computer is programmed to simulate the actual helicopter, receiving inputs from trainee operation of flight and other controls and directing appropriate responses from the motion system, control loading, aircraft instruments, visual system and aural cues. Malfunctions and emergency conditions are introduced during demonstrations and training flights to teach emergency procedures and to provide practice without danger to personnel or damage to equipment.

The computer aids in training program control by relieving the instructor of tedious, repetitive tasks and allowing him to more effectively aid trainee learning. The program also allows selected parameters of trainee and simulated aircraft performance to be automatically recorded and evaluated against a specified standard. Computer controlled demonstrations are provided to teach trainees proper control and operating techniques. Automated training features assure that each trainee receives standardized instructions.

Visual System

One or more visual presentations (out-the-window scenes and visionics displays) are provided for each trainee station. Details and capabilities of visual systems are provided for each type SFTS in paragraph 3.2 in the main body of the report.

2.1 SFTS Program Descriptions

2.1.1 CH-47C CHINOOK Flight Simulator

The CH-47C Flight Simulator is designed to provide training in normal operating and emergency procedures. The prototype model and production models consist of a trainee station, with positions for pilot and copilot trainees, that is an authentic replica of the aircraft. Included behind the cockpit is an instructor station and an observer station. The instructor station design and arrangement was based upon human engineering analysis of instructor's duties and the requirement for an effective instructor-trainee interface. The cockpit is mounted upon a six-degree-of-freedom motion system to provide roll, pitch, yaw, vertical, lateral, and longitudinal motion cues. A high resolution visual system consisting of a 1500:1 scale three dimensional terrain model 56 feet long by 24 feet high and a roving television camera that is synchronized with cockpit control inputs provides a display to each trainee that is viewed through the front windows. Each trainee has an additional display at the

chin window location consisting of computer generated symbology which provides relative altitude and motion indications when maneuvering near the ground at designated landing sites. The entire trainer is simulated by a DEC PDP 11/45 computer complex.

The trainer was determined acceptable for Army use during the DEVA IPR 31 May-1 June 1978 and, with the addition of a side window presentation, extension of the chin window coverage, and a sophisticated probe protection system, was recommended for type classification standard. These recommended changes were made on the production units, but not on the prototype.

The CH-47D CHINOOK Flight Simulator will simulate the Army Serial Number 81-23385 CH-47D Aircraft. The initial hardware and software baseline for the CH-47D FS is established by the CH-47C Flight Simulator production model. The major modifications required to the CH-47C FS production model include the simulation of the T55-L-712 Turboshaft engine, fiberglass rotor blade, cargo hooks, advanced flight control system, navigational and communication systems, aircraft systems, and survivability avionics equipment, the modified cockpit configuration, and the substitutions of a Computer Generated Image generator (CGI) visual system and a new technology digital voice system, a record/playback instructional audio system.

The CH-47D Flight Simulator will provide cockpit preflight and starting procedures, training in aircraft control, visual takeoff and landing procedures (including landing in confined areas), and pinnacle and load operations (excluding slope operations). In addition, the CH-47D FS performance envelope will extend from nap-of-the-earth (NOE) capability to the service ceiling of the aircraft.

2.1.2 AH-1S COBRA Flight and Weapons Simulator

The AH-1S Flight and Weapons Simulator is designed to provide training in normal operating procedures, emergency procedures and gunnery techniques including delivery of the TOW missile. The trainer consists of two cockpits representing the pilot and gunner stations respectively, with each mounted on its own six-degree-of-freedom motion system with the entire complex controlled by a PDP 11/55 computer system. Each cockpit is an authentic replica of the actual aircraft from the trainee station forward. An instructor station and observer seat are installed aft of the trainee stations. The instructor station design and arrangement is based upon human engineering analysis of the training situation and the requirements for an effective trainee/instructor interface.

The trainer includes a visual system that provides day and night visual cues to the trainees as well as weapons' effects. This high resolution visual system employs a closed circuit laser camera/television system with a three-dimensional terrain model. Two identical 64 feet long by 24 feet high models represent a part of the Fort Rucker training area approximately 11 by 4 nautical miles in area. A laser probe, synchronized with cockpit maneuvers, generates the visual presentation which is seen by the trainee and instructor through the front window. The pilot station also includes a side window to enlarge the field of view available to the pilot when required for certain maneuvers, such as autorotations. The two identical model boards provide the option of flying separate training missions for the pilot and the gunners simultaneously or the two cockpits can be linked together electronically and provide a team training capability.

2.1.3 UH-60 BLACK HAWK Flight Simulator

The production UH-60 BLACK HAWK Flight Simulator consists of a single cockpit mounted on a six-degree-of-freedom motion system which is computer controlled. The cockpit is an exact replica of the UH-60A aircraft from the trainee station forward. The visual presentation is provided by a Digital Image Generation (DIG) four window, three channel, full day-night visual system.

The UH-60 FS is designed to provide training in normal operating procedures, emergency procedures and continuation training. Continuation training is primarily oriented toward training and maintaining tactical flight skills. To simulate a tactical combat environment the DIG visual system provides for ground muzzle flashes and tracer effects, a ground to air missile signature, and moveable enemy tanks. The simulator is also capable of flight at a four foot wheel height over the entire gaming area, training in confined areas, pinnacle operations, sling loads and formation flight.

2.1.4 AH-64 APACHE Combat Mission Simulator

The prototype AH-64 Combat Mission Simulator will be designed to provide a training capability for flight and weapon delivery, normal and emergency procedures, and sensor system operation tasks required in the operational design basis helicopter. The simulator will consist of pilot and copilot/gunner trainee modules, instructor modules, motion subsystems, visual subsystems, and a computer complex. The pilot and copilot/gunner trainee modules will be replicas of the actual aircraft cockpits and each will be mounted on a six-degree-of-freedom motion base. The visual subsystem

will provide a current state-of-the-art out-the-window scene and sensor imagery to each of the appropriate crewmember video displays. Simulated imagery includes forward looking infrared (FLIR), day television (DTV), and direct view optics (DVO). Pilot displays consist of the integrated helmet and display sight system helmet display unit (IHADSS HDU) and a panel mounted video display unit (VDU). Gunner displays include the IHADSS HDU, a target acquisition and designation sight heads down display (TADS HDD) and a TADS heads out display (HOD). The simulator will be operated through the computer complex which will fulfill subsystem interface requirements. The training functions will be controlled from the instructor's station located behind each trainee module. The pilot and copilot/gunner will have the capability to train individually or may train as a team performing an integrated combat mission. The acquisition strategy provides for the integration of an advanced wide angle, high detail visual system being developed under a separate procurement for the production units. The advanced visual system will be developed in the Visual System Component Development Program (VSCDP) and will be retrofitted into the prototype CMS during the production phase.

2.1.5 Future Helicopter and Flight Simulator Development

a. LHX SCAT and LHX UTILITY Helicopter

The U.S. Army's Advanced Light Multipurpose Helicopter (LHX) program is presently in the concept formulation phase. Plans are for the LHX to be developed in both the SCAT (Scout and Attack) and UTILITY versions with the LHX UTILITY following the LHX SCAT development. The LHX eventually will replace the Bell UH-1s, OH-58s and AH-1s, and the Hughes OH-6s.

Two SFTS models are planned for the LHX, a Combat Mission Simulator (CMS) for the SCAT version and a flight simulator (FS) for the UTILITY version. The former will require a visual system which provides sensor simulation, visionic displays, targets, weapon effects and other special effects as well as out-the-window views comparable to the AH-64 CMS described in paragraph 2.1.4, above, while the latter will require out-the-window views necessary to support flight training. The SCAT version may have either a single pilot or a pilot and one other crewman or an initial pilot plus crewman version may be changed to a pilot only version through a Preplanned Product Improvement (P^3I) program. In either case a single visual system is planned. A single multichannel visual system is being considered for the two-man

crew version with visual channels shared by pilot and crewman positions mounted on a single motion platform.

b. Scout Attack Team Trainer (SATT)

A requirement is being formulated for a SATT that can be used to team train and task load the OH-58D, AH-1 and AH-64 helicopter crew members. Concept formulation has not been completed for the SATT and a best technical approach remains to be selected. Visual system requirements for the SATT, if any, have not been identified. Other requirements, quantities and ready for training dates have not been announced.

APPENDIX B

VISUAL SYSTEM COMPONENT DISPLAY PROGRAM (VSCDP)

PROGRAM DESCRIPTION

1.0 BACKGROUND

This program was established to accelerate the integration and system demonstration of next generation visual simulation technology to support simulated helicopter nap-of-the-earth (NOE) flight over large gaming areas and at the same time to provide visual and nonvisual spectral scenes, special effects multiple viewpoints, view directions, magnifications and fields of view. The VSCDP is being conducted concurrently with the development of the AH-64 APACHE Helicopter Combat Mission Simulator (CMS), Device 2B40, which is described in Naval Training Equipment Center Specification 222-1162B. Upon successful demonstration, the Visual System Component (VSC) reflecting next generation visual simulation technology developed under this program will be produced to replace the interim Computer Generated Imagery (CGI) visual system of the AH-64 CMS as a Preplanned Product Improvement (P^3I).

The Army has stated that visual simulation technology (including the interim AH-64 CMS CGI) is unable to provide presentation of out-the-window scenes over wide effective fields of view with scene detail adequate for simulated NOE helicopter flight. Current model board systems provide imagery of sufficient detail to support NOE tactical flight maneuver training. However, they are limited to narrow effective instantaneous fields of view, single viewpoints and view directions per modelboard, single spectrum responses, and the lack of special effects such as moving targets and weapons effects. Current CGI systems can provide large gaming areas represented in more than one spectral region, special effects, multiple viewpoints and multiple magnifications, but have limited processing capability. Current CGI limitations in data base development and image processing capability and the resulting lack of foreground scene detail do not provide the desired fidelity in the simulation of NOE helicopter flight and training in NOE helicopter tactical flight maneuvers.

2.0 PROGRAM DESCRIPTION

The VSC is being developed to meet the CMS visual requirements at reasonable cost and with acceptable risk using advanced visual simulation technology, including:

- o Automated data base generation and modification.
- o Projected OTW displays with low resolution, wide angle background (BG) and high resolution area of interest (AOI) FOVs positioned from head and eye tracker data.
- o Computer Based Imagery (CBI).

The VSCDP was separated into two phases. Phase I studies completed in 1982 by three contractors working independently, consisted of analysis of helicopter flight and combat mission training requirements, descriptions of demonstrated visual simulation capabilities, affordability, and a concept design and analysis of a particular approach to meet the full visual simulation requirements of the AH-64 CMS and other synthetic flight training systems. Contracts were awarded to two of the four Phase I contractors to proceed with the Phase II VSCDP:

- o Honeywell Training and Control Systems Operations.
- o General Electric Simulation and Controls Systems Department.

Other experienced visual simulation developers and manufacturers have expressed their intentions to develop systems to meet the VSC requirements and to demonstrate these systems to the Government during the VSCDP Phase II effort. These include the following:

- o Evans and Sutherland.
- o Grumman.
- o Singer Link.
- o Hughes.
- o Vought.

c. The VSCDP Phase II contracts were awarded early in 1983 and provided for the following:

ITEM AND DESCRIPTION	CONTRACT COMPLETION DATE	EARLIEST PROPOSED COMPLETION DATE
1. Proof of Concept Demonstration Each contractor will demonstrate the fundamental technology advances key to his proposed VSCDP upon existing/modified hardware or breadboards. This initial demonstration/evaluation (D/E1) will show a "proof of concept" type demonstration. This demonstration shall demonstrate that the concept originally proposed to the Government is able to operate to a limited extent. The term "limited extent" is meant to imply to the depth necessary to show proof that concepts are transferable to an operational capability.	April 1984	September 1983
2. Display/Image Generator Demonstration Each contractor will demonstrate his Display/Image Generator Subsystem and the capability of the VSCDP hardware to integrate with the Image Display Subsystem. The demonstration will be conducted upon the brassboard VSCDP hardware and is designated D/E2.	January 1985	July 1984
3. VSCDP Demonstration/Evaluation Each contractor will provide all support services necessary for adequate system performance. Each contractor will deliver the necessary software media (i.e., magnetic tapes, magnetic disks, punch cards, etc.) required to operate the VSC for the duration of the Full-Up Demonstration, Test and Evaluation (D/E 3) to the PCO's Technical Representative. Each contractor will perform required maintenance of the VSCDP but shall not change the hardware or software configurations without prior written concurrence of the PCOTR.		

ITEM AND DESCRIPTION	CONTRACT COMPLETION DATE	EARLIEST PROPOSED COMPLETION DATE
a. VSCDP Technical Demonstration, Test and Evaluation	September 1985	April 1985
The requirements and goals of the Statement of Work, VSCDP Hardware Development will be tested and demonstrated by the contractor under Government direction in accordance with the approved Trainer Test Procedures and Results Report. A Physical Configuration Audit per MIL-STD-1521A shall also form a part of this D/E 3.		
b. VSCDP Operational Suitability Demonstration, Test and Evaluation	October 1985	May 1985
The Government will conduct an Operational Suitability Demonstration, Test and Evaluation. This nonstructured, free play DT and E may include, but is not limited to:		
o Location of Government "pilot" at VSC eyepoint with ability to control in real time pitch, yaw, roll, heading, velocity and associated rate changes.		
o Real time landings in the data base.		
o Nap of the earth (NOE) flight.		
o Exercise of special features within the VSC (i.e., weapons delivery and special effects).		
4. Interface/Integration with AH-64 CMS Program	March 1983 to October 1985	
Paragraph b., below, provides general guidance for the VSCDP/AH-64 CMS Interface. The AH-64 CMS development is defined by Contract N61339-82-C-0088. The following additional requirements apply.		

ITEM AND DESCRIPTION	CONTRACT COMPLETION DATE	EARLIEST PROPOSED COMPLETION DATE
a. Each contractor will make every effort to ensure that the VSCDP and AH-64 CMS systems are compatible. Compatibility covers hardware, software, and support considerations. Hardware compatibility will ensure that the VSCDP is able to interface and integrate with AH-64 CMS mechanically, optically and electrically. Software compatibility will ensure VSCDP software is compatible with the AH-64 CMS (e.g., use of FORTRAN). Support interface will ensure that such items to include, but not limited to, maintainability and logistics support concepts are compatible with the AH-64 CMS. A producibility engineering planning effort shall also be a part of the VSCDP/AH-64 CMS integration/interfacing.		
b. The AH-64 Combat Mission Simulator (CMS) Program is to be interfaced with the VSC so as to allow incorporation of the developed advanced visual system into production units of Device 2B40. In order to minimize the risk in integrating the products developed in the VSCDP with the production units of Device 2B40, it is required that liaison between the VSCDP contractor and the 2B40 manufacturer be established and an exchange of information take place. To assure that the interface requirements of specification N222-1162B are met, each contractor is required to: (1) appoint a central point of contact to interface with the Device 2B40 contractor; (2) provide technical representation at Device 2B40 design review conferences; (3) review technical documentation generated under the AH-64 CMS program; (4) provide the Device 2B40 contractor with data and information necessary to accomplish the integration; and (5) provide for the Device 2B40 contractor attendance at design review conferences.		

system will interface with the AH64 Helicopter CMS, Device 2B40; interface requirements will be specified, and Producibility Engineering and Planning (PEP) will be initiated in Phase II. Requirements for PEP are to be added to the Phase II contract, and requirements for development of interface design specifications for interface of the VSCDP visual system with SFTS must follow the Phase II VSCDP and the SFTS contracts. SFTS facility requirements must be reviewed for their applicability to the VSCDP visual system and modification undertaken early in the Phase II VSCDP where indicated.

The production VSCDP visual system will have an assortment of capabilities, all of which will not apply to a specific SFTS. Thus, *in any production procurement* the VSCDP visual system will not be ordered as a unit. Instead, visual system capabilities in areas such as the following will be selected for a particular application:

- Interface and integration
- Number, type and details of visual channels
- Data base(s) requirements
- Visual gaming area and special landing area requirements
- Special requirements (true IR simulation, laser ranging)
- Number, type and motion of ground targets and friendly vehicles
- Number, type and motion of aircraft targets and friendly aircraft
- Weapons effects (trajectories, tracers, guidance, explosions, hit effects)
- Special conditions
- Visual system utilization and operating modes (multi-crew position SFTS)
- Multiple viewpoints
- Multiple spectral regions

4.0 ATTACHMENTS TO APPENDIX B

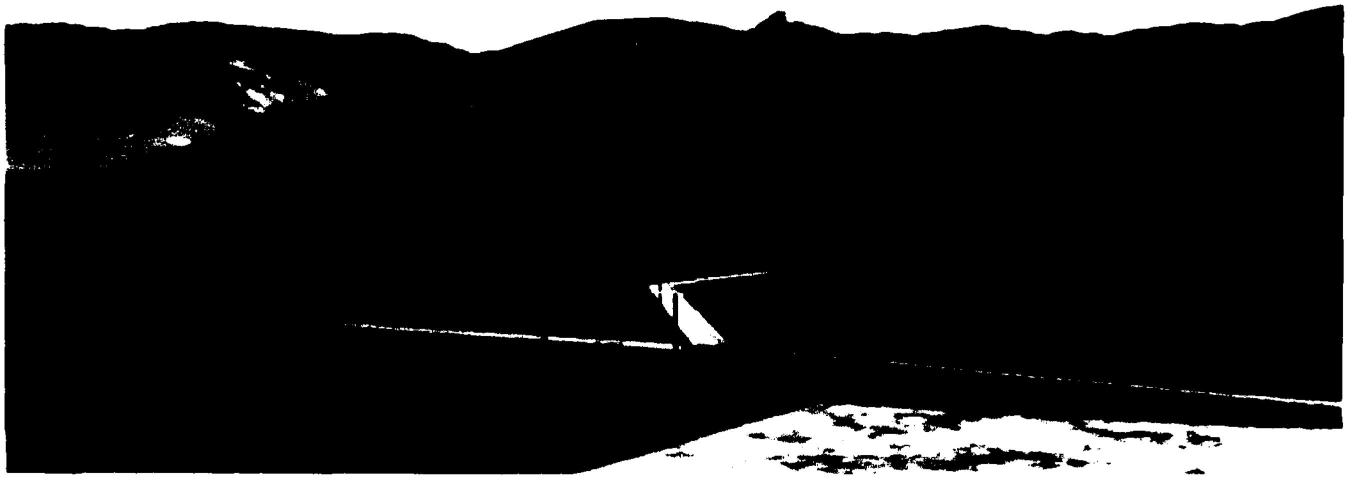
Attachment 1 is information supplied by General Electric which describes their proposed visual system.

Attachment 2 is information supplied by Honeywell which describes features of their proposed visual system.

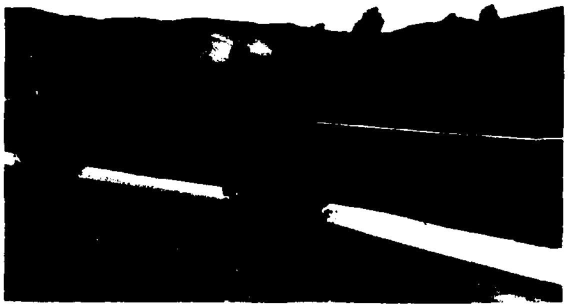
Attachment 3 is information which describes the projection system to be used to demonstrate Honeywell's VSCDP image generation system.

Advanced Visual Technology System (AVTS)

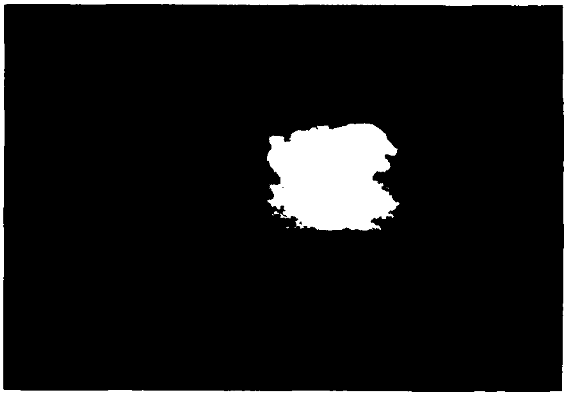
The Advanced Visual Technology System successfully meets a combined U.S. Air Force and Army requirement for combat training research. It will provide an ideal visual environment for the evaluation of low-altitude, fixed-wing tactics and helicopter, nap-of-the-earth missions.



From the outset, the AVTS has been designated by the Air Force Human Resources Laboratory (AFHRL) to provide effective visual simulation of the low-altitude, fixed-wing environment, as well as to provide capability for air-to-air combat and conventional airfield operations. Emerging U.S. Army requirements for combat helicopter training have led the Project Manager for Training Devices (PM-TRADE) to augment AFHRL resources, through the Visual System Component Development Program (VSCDP), to strengthen the AVTS effort. The objective is to direct AVTS development in such a way that it will satisfy both Air Force and Army requirements for low-level visual training. This combined mission synergy places the AVTS program at the forefront of visual simulation technology.



Using an image generator design that produces cell-textured scenes of photographic quality, the AVTS design concept obtains even greater fidelity by applying an innovative display approach in which the greatest scene detail is concentrated in those areas currently being observed by crew members. This area-of-interest display system features unique blending and brightness enhancement functions which overcome the major problems associated with area-of-interest display design. In keeping with its additional role as a developmental vehicle, the AVTS image generator is designed to drive any type of display system.



This application of advanced image generation and display technologies not only meets known requirements for fixed-wing and helicopter operations, it also provides AFHRL and PM-TRADE with a vital decision-support capability. The AVTS will be the key investigative tool in the AFHRL mission of technology development. Its application will enable a thorough and systematic evaluation of the full potential of Computer Image Generation (CIG) technology set against the measurement of real training needs.

ATTACHMENT 1

U.S.A.

ADVANCED VISUAL TECHNOLOGY SYSTEM — CAPABILITIES

SCENE CONTENT With the advent of cell texture technology it is possible to portray photographic image quality combined with the flexibility of real-time computer image generation. In this type of system, traditional measures of scene content may be applied but they do not adequately describe scene realism. Applying such terminology, 4000 faces (polygons and circles) and 4,000 point features can be processed simultaneously by the AVTS at 60 Hz update rate, for a single viewpoint. The system may also be configured for dual viewpoint applications.

Each face in the environment can be designated to be covered with either a cell texture or conventional texture pattern. Cell texture patterns will portray photographic image quality without consuming feature resources. Both forms of texture maintain the perspective accuracy and image quality of the underlying face, regardless of orientation.

OCCULTING A unique algorithm developed for AVTS provides the capability for low-level flight through rolling terrain with large numbers of fixed and moving models.

DYNAMIC FEATURES Up to 128 features in the scene, which are capable of movement, can be provided. These features include moving models, articulated parts of moving models, projectiles, smoke, flak, flares, and weapon effects.

STATIC FEATURES Trees, rocks and shrubs may be scattered or grouped as required on every terrain face in the environment for an unprecedented density of ground clutter or 3-D texture.

VERSATILITY The architecture employed improves image quality and enables the AVTS image generator to provide output that is compatible with all known and future types of displays.

IMAGE DISPLAY SYSTEM The AVTS provides a powerful image display system in addition to the image generation system described above. This system provides an area-of-interest display that is directed by an Eye/Head Tracker and projected on a spherical dome projection screen. Unique design features provide blending and brightness enhancement capability to overcome the major problems hitherto inherent in area-of-interest design. The Image Generator provides a predistorted image to the projectors that results in an undistorted image at the dome viewpoint.

VISUAL DATA BASE A Data Base Generation system is included with the AVTS that will allow semiautomatic preparation of visual data bases derived from Defense Mapping Agency information, with any degree of augmentation required for specific areas.

DESIGN OF A REAL-TIME CGSI SYSTEM*

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Abstract

A hybrid system, CGSI, is being developed which will merge the attributes of video disc technology and Computer Generated Imagery (CGI). Initial non-real time feasibility has been demonstrated and reported on. Detailed design of a limited real-time system is being conducted. The basic design is modular with a parallel pipeline architecture. This real-time design is the topic of this paper.

Introduction

Requirements and Applications

The rapid development and increased use of sophisticated imaging sensors in conjunction with the real world visual scene have expanded the capabilities of most military systems. Figure 1 illustrates the complexity of the simulation problems for: a) the Navy's F/A-18 cockpit, and b) a scene taken from the window of an Army helicopter flying nap of the earth (NOE). The new capabilities require simulations to evaluate and verify system operations before production, to train the operators before assignment and to maintain proficiency. This simulation and training is more difficult and important because: the information content of imaging sensors is high, the data is now novel to the observer, and the operator workload is very high. Testing and training with the actual equipment in the real environment is valuable. However, high equipment cost, high maintenance cost, availability of fuel, risk factors, and lack of suitable conflict scenarios reduces test and training efficiency. The great challenge of simulation today is the simulation of high fidelity multiband imagery sensor correlated with the out-the-window simulated visual scene.

Hybrid system concepts such as Computer Generated Synthesized Imagery (CGSI) offer near-term solution for simulating sophisticated sensors and correlated visual-sensor imagery. Because of the high potential payoff from the real-time implementation of CGSI, NAVTRAEQUIPCEN, with support from PM TRADE, funded Honeywell's Systems and Research Center in 1981 to provide a non-real time demonstration of CGSI for a NOE flight and a preliminary design for real-time implementation

(a) Reprinted from Naval Aviation News, Nov. 1982

(b) Helicopter NOE flight, view out the window.

Fig. 1 Simulation Complexities

*Reprinted, with permission, from AIAA Flight Simulation Technology Conference Paper No. 83-1101

of CGSI.[1, 2] In addition to displaying individual objects in a scene, the system is capable of displaying groups of objects, imagery as seen from various sensors and adding special effects.

The system design is modular with a parallel pipeline architecture to allow one to configure a system with as many object generators or pipelines as necessary to provide adequate scene detail.

Although the initial non real-time feasibility has been demonstrated, additional work is necessary and being pursued to provide a real-time capability (i.e., a minimum update rate of 30 Hz). This work is currently funded by NAVTRAEQUIPCEN and PM TRADE with some support from the Air Force Human Resource Laboratory. Detail design of a limited system is being conducted with completion in April 1983. Fabrication of a single pipeline will be completed in August 1983. CGSI pipeline processors will be interfaced to NAVTRAEQUIPCEN's Visual Technology Research Simulator (VTRS) facility in 1984 for evaluating CGSI concepts and for demonstrating simulation of coordinated multisensor displays (visual and FLIR).

The CGSI system is a candidate for a competitive flyoff for next generation visual technology for the AH-64 simulator. The U.S. Army visual requirements encompass weapons effects and delivery, wide field of view displays to support nap-of-the-earth flight, multiple viewpoints, multiple sensors and multiple magnifications through a telescoping system. These requirements are felt to be one of the most demanding in the simulation industry today. The Honeywell CGSI system could provide a capability to meet these requirements. The CGSI system has potential application for providing air-to-ground capability in the Navy's F/A-18 Hornet fighter/attack aircraft simulators and for filling nap-of-the-earth training requirements on the CH-53 D/E and CH-46 helicopter simulators. One of the extremely attractive features of this approach is the potential for utilizing CGSI to retrofit existing CGI systems and enhance the scene content. The Air Force's interest in this development results from the need for high fidelity simulation for air-to-ground attack missions.

CGSI Background

The strength of Computer Generated Imagery (CGI) is its ability to generate surface representations. A real or artificial surface can be measured to get elevations at specified points, usually at intersections of a uniform grid. The scene can be constructed in a computer by connecting the sample elevations and placement of objects (trees, rocks, shrubs, houses, roads, etc.). The weakness of CGI is the lack of fidelity and detail; the objects appear cartoonish.

Computer Synthesized Imagery (CSI) uses high fidelity photographs of real scenes. The objects in the scenes are not represented individually; nor is the scene modeled by elevation profiles. Usually the scene is held static, while single objects, like aircraft or tanks, move within the scene. The high-fidelity CSI scenes are limited to the viewpoint of the camera. That is, one cannot drive through a scene unless a series of through-the-scene photographs is used.

Computer Generated Synthesized Imagery (CGSI) combines the best features of both technologies: CGI and CSI. A scene is constructed by placing individual high-fidelity CSI objects on a specified CGI surface. A CGSI scene is constructed much like a CGI scene. The surface elevations and object locations are laid out on a uniform grid. The individual objects used in the scene are transformed for perspective and size. This includes size, position, rotation, warp, and intensity transformations on the image. The surface may be a CGI texture or a series of CSI surface inserts. The CGSI scene may be constructed with imagery from any portion of the spectrum—visual, infrared, millimeter, or radar frequencies.

CGSI System Overview

Figure 2 is a functional overview of a real-time CGSI sytem.

- Data Base Construction. The data base consists of two very different types of data: the object library and the gaming area. The object library contains images of objects and surfaces, and transmissivity masks of special effects from one to many bands of the spectrum. This allows the simulation of various sensors. The gaming area data base provides the information necesary for placing the contents of the object library, objects, surfaces, and special effects on a grid or gaming area. The objects in the library may be either stationary or capable of movement.

- Vehicle Simulation Computations. The vehicle simulation computations, based upon the vehicle math model and control inputs, determines the locations and viewing direction of the visual or sensor system for the primary vehicle.

- Systems Interface. The I/O of the vehicle simulation system and I/O of the CGSI system must interface in an efficient manner.

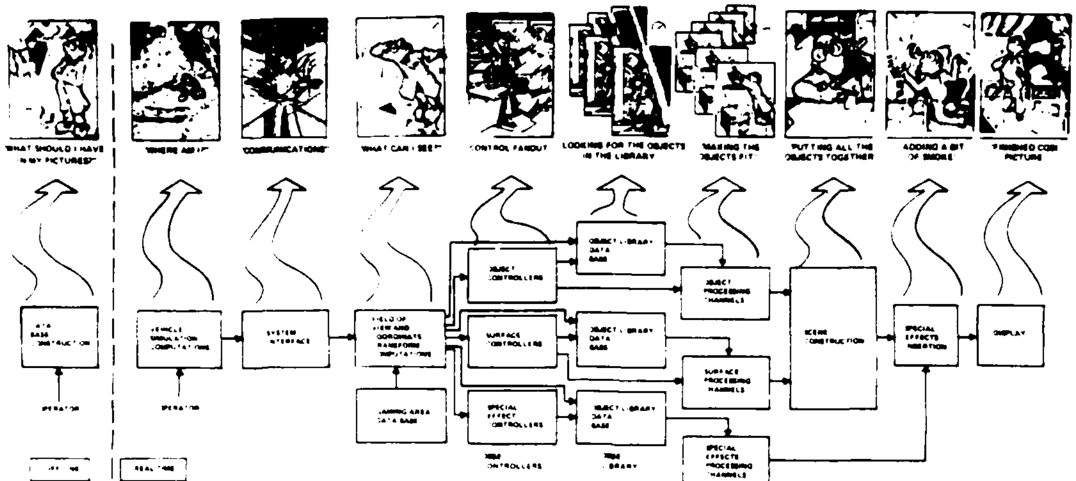


Fig. 2. CGSI Functional Overview.

o **Field of View (FOV) and Coordinate Transform Computations (OSSE).** The FOV processor determines the presence of objects, surfaces, and special effects in the scene under construction. The output of a transformation matrix (V) converts the real-world coordinates to screen coordinates.

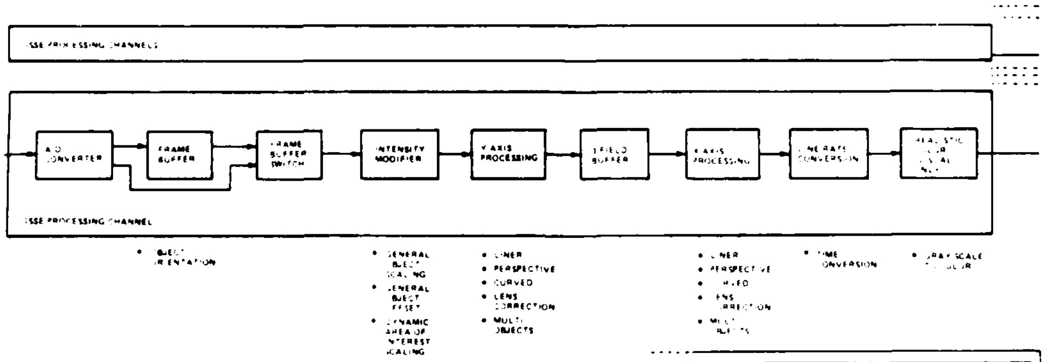
o **Object/Surface/Special Effects Controllers.** The controllers fan out and process the control functions generated during the FOV computation. The processed control functions are passed to the object/surface/special effects processing channels.

o **Object/Surface/Special Effects Library.** The library stores the images used to construct a scene. The controllers command the selected images which are passed to the processing channels.

o **Object/Surface/Special Effects Processing Channels.** The individual processing channel pipelines process one object, surface or special effect per channel. All the processing channels operate in an identical manner: large object, small object, surface or special effect. That is, the object, surface, special effect processing char vels change a stored image (normal perspective) to scene conditions (screen coordinates) by changing image, position, size, rotation and warp. Image intensity is modified based upon range and object type.

o **Scene Construction.** The scene construction module takes the individual image from each processing channel, separates the image from the background, and assembles the scene based upon range. The high frequency edges generated by assembling a scene from individual images are smoothed matching edge and internal frequencies.

o **Special Effects.** Special effects are added after the generation of the scene based upon range.



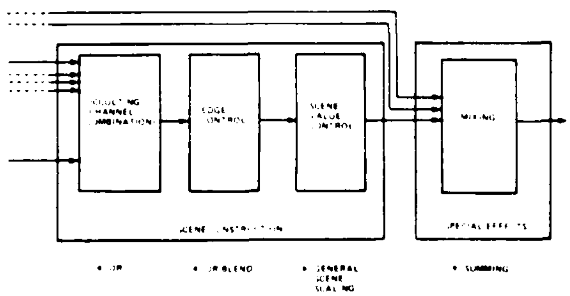


Fig. 3 OSSE Processing Channels, Scene Construction, Special Effects

ATTACHMENT 2

CGSI Real-Time Functional Overview

The preceding sections presented a CGSI introductory overview. This section examines the detailed functions available in CGSI simulations. Figure 3 is an expansion of the OSSE Processing Channels, Scene Construction and Special Effects shown in Figure 2. The remaining parts of Figure 2, not shown in Figure 3, either provide control functions or data storage functions which do not modify the image. It is the intent of this design to allow the system to produce any type of imagery; i.e., visual, IR, MMW, SAR, radar, etc.

OSSE Processing Channels

The OSSE processing channels prepare each object, surface or special effect (OSSE) for insertion in the scene as the scene is constructed on a pixel-by-pixel basis. Systems under consideration contain from four to more than one hundred OSSE channels. Some systems may require all of the capabilities reviewed and others may require only a selected number.

A/D Conversion. A high speed A/D module converts the analog video imagery to digital data. The module operates near 10 MHz and provides 8-bit, or 256 gray-shade, output.

Frame Buffer. The frame buffer is used to store images that are not changing. This includes small 2D objects, surfaces and special effects. The warping process may compress data if the image is rotated beyond 50 or 60 degrees. By using a high speed memory design with access in both the X and Y axis, one image may be rotated a full 360 degrees.

Frame Buffer Switch. The frame buffer switch allows the imagery to be held in the frame buffer for repeated use of 2D objects, surfaces and special effects. After an OSSE is stored in the frame buffer, the optical disc may supply imagery to other channels. For dynamic 3D objects, the frame buffer switch allows the imagery to be taken directly from the optical disc without any delays. The frame buffer switch is controlled by the OSSE controller.

Intensi y Modifier. The intensity modifiers modify the intensity of a scene in both global and local manners. Global changes use a look up table (LUT) and provide the following:

- General Object Scaling. This changes the slope of the gray scale. The change may be linear or non linear.
- General Object Offset. This raises or lowers the general intensity of the object. As an example, these changes may be associated with ranges. That is, an object at a great distance is more saturated, bluer and darker than the same object at a very short range. Local modifiers change just part of any object by using multiplier modifiers in a real time basis.
- Dynamic Area of Interest Scaling. This changes each pixel by a slightly different value to obtain a slope or gradient. As an example, an object may be modified to represent the sun shining on the side of a tree as shown in Figure 4.

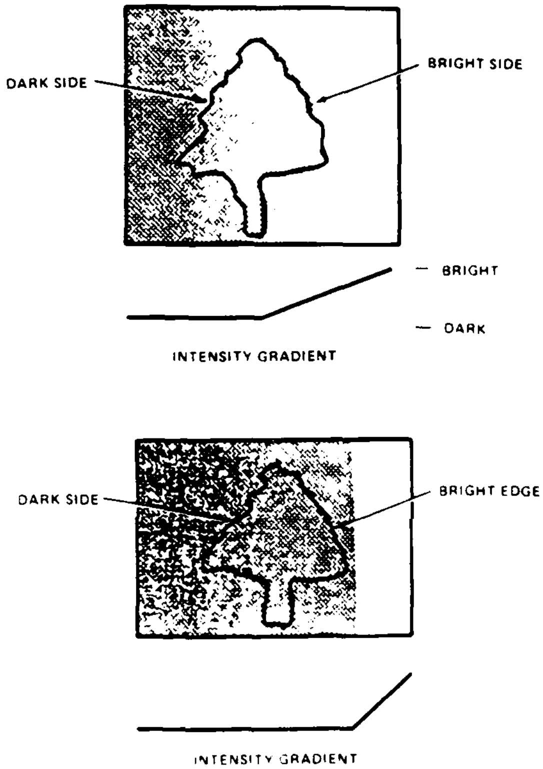


Fig. 4 Intensity Gradient.

Y Axis Processing. The algorithm for distorting an object operates in two passes as shown in Figure 5. Before explaining the Y axis functions, an overview of the warping function is presented. The warping algorithm contained in the pipeline operates in two passes; first the Y axis and then the X axis. Figure 6 shows the warp function components. The field microprocessor determines the offset (starting location), the magnification (change of line length) of the first line in each axis and selects the field memory buffers. The line microprocessor determines the delta (▲) offset and delta (▲) magnification of each line.

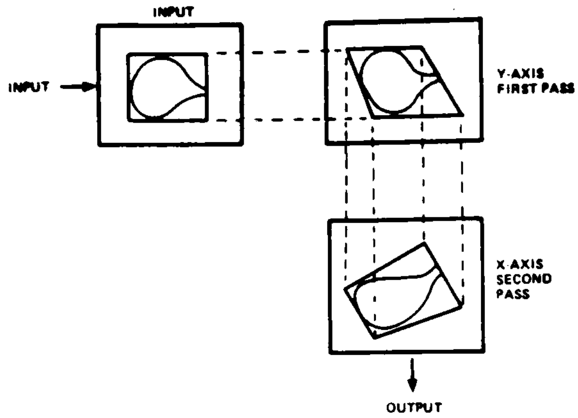


Fig. 5 Warp Processing.

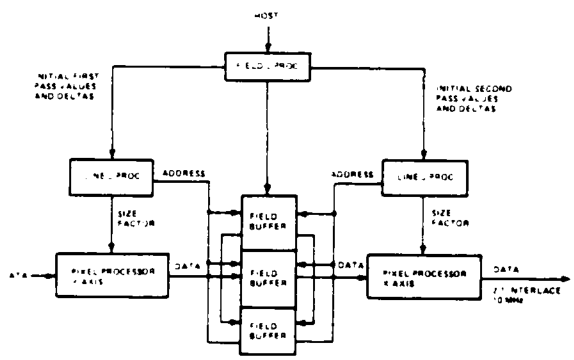


Fig. 6 Warp Function.

The field microprocessor operates in a 16 millisecond cycle and the line microprocessor in a 63 microsecond cycle. The pixel processors operate on the pixel streams in a 100 nanosecond cycle or 10 MHz.

During the first pass of the Y axis, each line in the row may be distorted in one or more of the following manners (Figure 7):

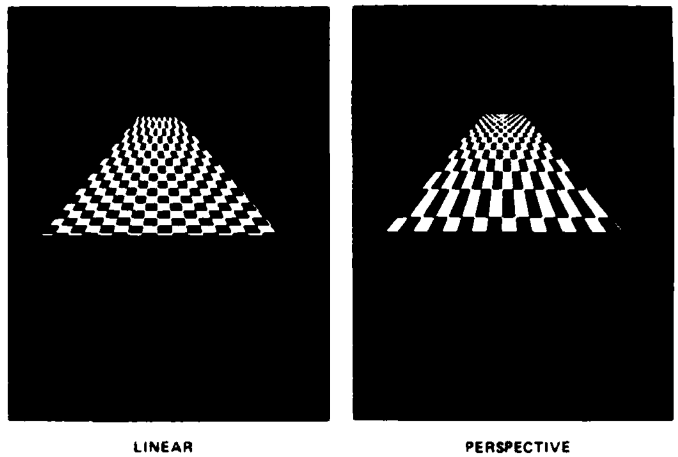


Fig. 7 Runway Applications.

- Linear. The pixels in the image in the Y axis are scaled in a linear manner by using an offset and magnification. The offset is a constant for the entire frame and the magnification is constant for each line. This approach makes a long runway curve up at both ends. See Figure 7a.

- Perspective. The pixels are scaled in a nonlinear manner. Each offset and magnification is different due to the nonlinear range variable. This approach keeps the internal detail of a flat surface in correct perspective. The runway does not curl up at the ends. See Figure 7b.

- Curved. A hemisphere may be distorted to appear flat (a common technique used in map making). By using nonlinear offsets and magnification, the distorted flat surface may be restored to sphere from any desired view angle. The tank turret shown in Figure 8 is an excellent example.

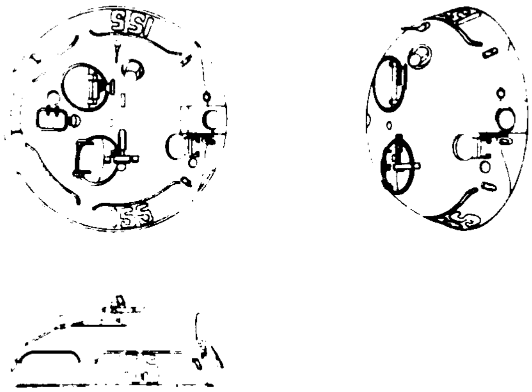
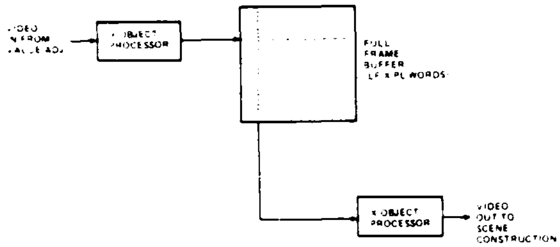


Fig. 8 Tank Turret.

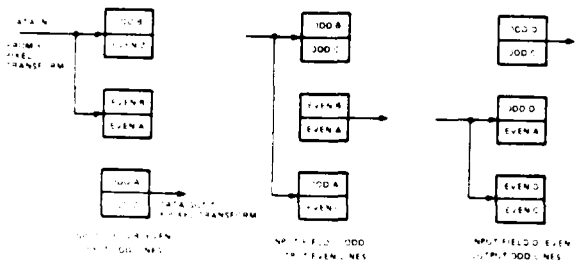
- <u>Lens Correction</u>. Lens and spherical projection surfaces may require distortion corrections. Major distortion corrections may be made at the offset level and minor corrections made at the magnification level.

- <u>Multi-Objects</u>. Most scenes contain many small objects and only a few large objects. To obtain maximum use of a pipeline, many small objects (4, 9, 16, 25) may be processed rather than one large object. This is achieved by changing the offset and magnification factors each time a new object is encountered in a line which would require a perspective warp algorithm.

<u>Three Field Buffer</u>. The three field buffer allows the Y axis processed image to be read into two field buffers, one for odd pixels and the second for even pixels. The third field buffer allows either odd or even fields to be processed in the X axis processor. This configuration is shown in Figure 9.



(a) Conceptual Frame Buffer



(b) Data Flow in Frame Buffer.

Fig. 9 Three-Field Buffer.

<u>X Axis Processing</u>. The techniques used in the X axis can be identical to those used in the Y axis which includes the following functions:

- Linear
- Perspective
- Curved
- Lens Correction
- Multi-Objects

In addition, for potential applications where perspective distortions in the real world are not identical to the X and Y axis, the X axis processing could use algorithms which differ from the algorithms used in the Y axis. This case could occur with dome projection display systems or Synthetic Aperture Radar (SAR) imaging systems.

<u>Line Rate Converter (LRC)</u>. Various applications require different line ratios. The standard pipeline operates at 525 video lines. The line rate converter changes the line rate of 525 lines to 875 or 1024 lines by changing the pixel clock rate. The line rate converter does not add lines or pixels; it only changes the rate at which the pixels are clocked in and out. In converting a 525 line system to 1024 lines, for example, only one fourth of the 1024 system is covered by a single 525 line output. The line rate converter is a first-in/first-out buffer (FIFO). The implementation is basically that of a very high speed two-part memory. Object image data is written into the memory in the 512 x 512 format at a 10 MHz pixel rate. At the same time, scene image data is read from the memory in the 1024 x 1024 (or 875 x 875) format at a maximum 40 MHz pixel rate.

<u>Realistic Color</u>. The CGSI approach has been developed to provide monochrome; realistic color; or true color capability. True color is provided through the creation of three spectrally distinct (red, green, blue) for each full color photograph.

When a full color image is displayed, the red, green and blue object images are independently processed and delivered to the red, green and blue channels of the color display system used. One can see that full color is bought for a price: three times as many processing channels are required relative to the number needed to generate a monochromatic version (e.g., IR) of the same object image.

Near perfect color is achievable in a much more economical manner. Most OSSEs contain only shades of one or two colors. Consider green leaves and camouflaged targets. To obtain realistic color, each object is stored as a black and white image. Associated with each image is a red, green and blue LUT conversion that assigns up to 256 colors to gray shade levels of the image. The 256 colors that are achievable may be 256 shades of one hue—for example, shades of green to create a high fidelity color image of a bush—or 256 distinct hues.

<u>Scene Construction</u>

The scene construction module assembles the individual objects being processed into a single scene (or picture). Near objects

occlude detail objects. Figure 10 demonstrates the warping and assembling of a house in a scene based upon range.

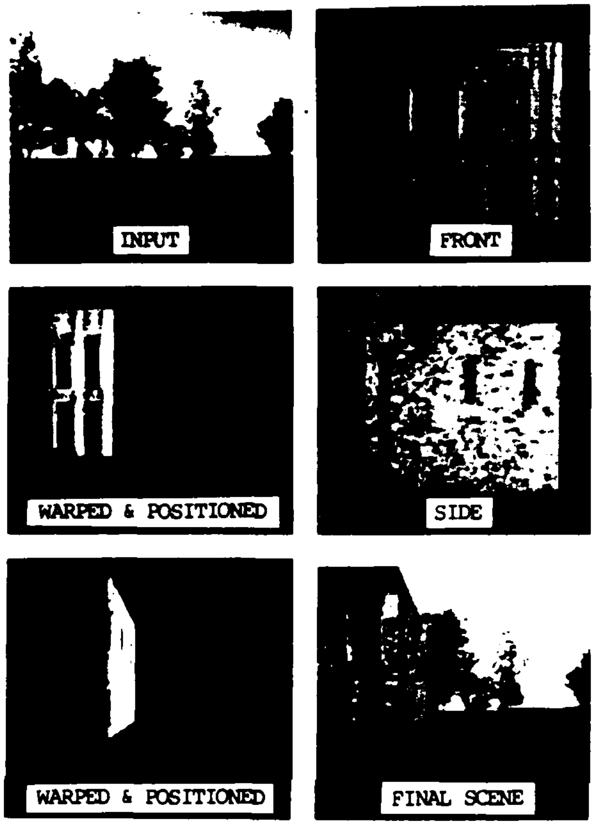


Fig. 10 Construction Scenes.

Occulting. The pipeline combiner or function used on a "binary tree" selection algorithm forms the heart of the scene construction module. Video data from multiple sources (or pipelines) is combined on a pixel by pixel basis. Near pixels occlude more distant pixels. The term "pipeline" is used here to refer to a source of video data. Each of these sources may be expanded to include one or more colors. As shown in Figure 11, the object switch element accepts (objects and surfaces) video data and range information from either the OSSE controller or the previous object switch. The object switch then outputs the selected video pipeline and the appropriate range of that channel.

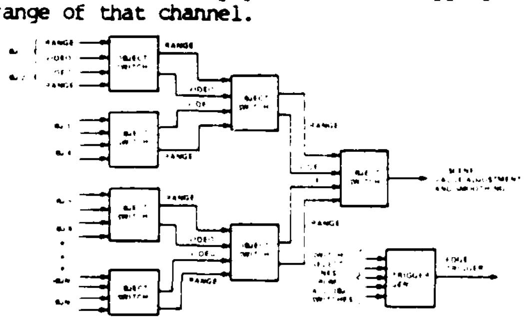


Fig. 11. Object Switch.

Edge Control. During the processing, the individual object in the OSSE processor, background pixels at the edge of the object, may become mixed with the object pixels. If the background is dark, a dark halo is formed around the object. This artifact is easily removed by adding a pixel around the perimeter of the object during threshold processing when the OSSE library is being constructed. It is this extra pixel that becomes mixed with the background during OSSE processing. In constructing a scene, in the visual domain, the edge control process uses the mixed pixel to determine the amount of the adjacent object pixel and the amount of the adjacent background pixel used to generate a new mixed pixel. In the IR and other sensor domains, a Gaussian spread function is used across several of the edge pixels to match heat, sensor roll off and other edge effects.

Scene Value Control. The scene value adjustment is used where scene-wide intensity corrections are required. Such corrections may be applied to compensate for day/night lighting, haze and rain. These are typically initial conditions, or very slowly changing conditions.

Special Effects

These translucent objects (smoke, fog, dust, shadows, haze, etc.) overlay the solid objects. These objects are stored as a mask which defines the outline, shape and transmissivity factor. The mask determines the combining percent of object/special effects. A second variable controls the intensity or color of the special effect object. The warp algorithm is used to distort the special effects and a series of frames are used to generate the motion.

The data (the mask) in the object library determines the percent of background objects present and the percent of special effects present by the following equation:

$$\text{Pixel Value (gray level)} = B + T\,(S - B)$$

This is shown in Figure 12. A series of special effects are described to demonstrate the capability of the system.

Dynamic Dust/Smoke. A dust/smoke mask defining the outline and transmission factors is generated by an artist based upon picture and mathematical characteristics of the dust/smoke. The top and bottom must be in the same location and have the same width as shown in Figure 13. Next a series of frames (480) are generated. Each line is incremented one or more lines in the Y axis when the frames are played back. This produces a continuous circulatory loop. This is shown in Figure 13.

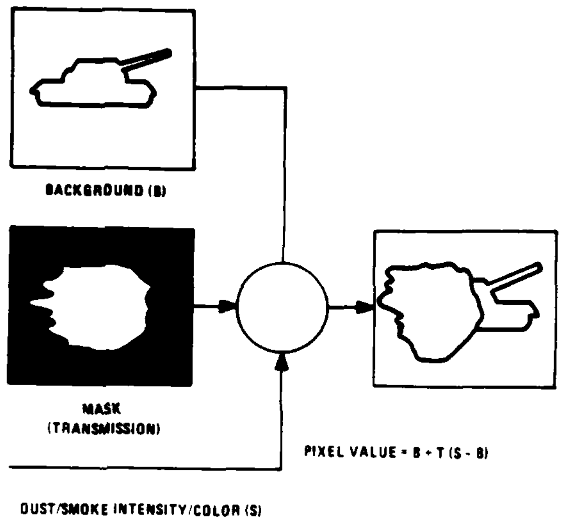


Fig. 12. Dust Smoke Algorithm

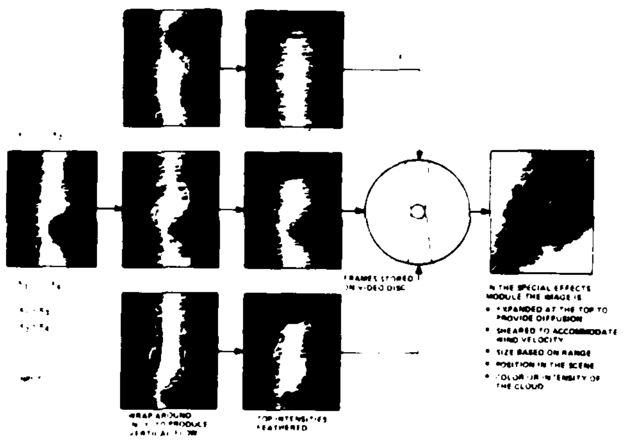


Fig. 13. Dynamic Smoke.

Next, the top of the dust/smoke cloud in each frame is featured to match the dispersant of the smoke in the atmosphere. The frames are stored in sequence on a video disc as shown in Figure 13. The warp algorithm, Figure 13, in the special effects processor is used to:

- o Expand the top to simulate diffusion
- o Shear the image to accommodate wind velocity
- o Size the cloud based upon range
- o Position the cloud in the scene

An initial condition parameter sets the color or intensity of the cloud. The rate at which the dust/smoke fumes are played back determines the rate of flow.

Shadows. Shadows are treated as translucent objects like dust and smoke. The transmission masks for shadows are generated from images in the object library. The transmission mask, a shadow, is created by setting all the pixels in an object to one gray level. The gray level determines the transmission of the shadow. In the gaming area, the four reference points of an object are projected to the surface. The new points on the surface are shadow reference points. The shadow, transmission mask, is warped to fit the scene based upon the shadow's reference points, Figure 14.

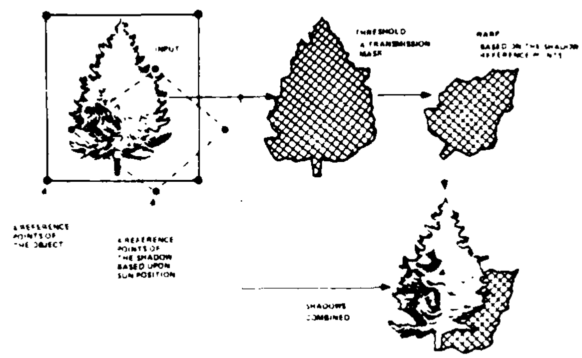


Fig. 14. Shadows.

Glint and Glare. Typically, glint and glare are computed from the surface normal data. However, in a CGSI system, unless the objects are developed from CGI nodal data, the normal data is not available. To produce glint and glare, a sector mask is developed based upon the glint and glare bright areas produced by different sun angles, Figure 15. The sectors in the mask are gray level. That is, when stored in the object library, sector 1 may have a luminance value of 8, sector 2 a value of 16, etc. The sun angle table data sets the look up tables in the object processor. If the sun is in sector 2, the input value of 16 in the look up table sets the output glint and glare values to a predetermined level. The remaining output values in the lookup table are zero. The result is a bright spot in sector 2. As the turret moves or the sun moves, the sector changes. In this procedure, dynamic glint and glare is based upon sun and vehicle movement.

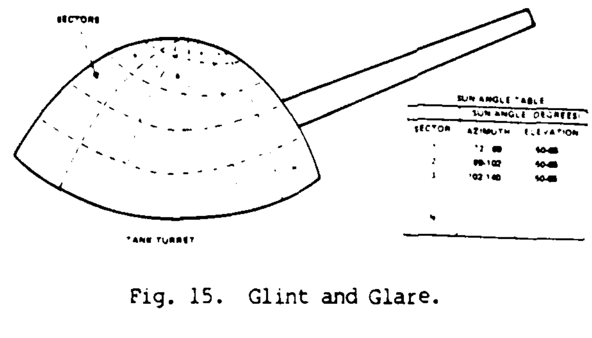


Fig. 15. Glint and Glare.

Hardware Overview

The high data rates of the video data, 10 MHZ, requires special purpose hardware where the flow of imagery is involved. However, the controllers of the special purpose hardware may be an off-the-shelf microprocessor. Figure 16 shows a possible implementation configuration using off-the-shelf components.

simulator (VTRS) facilities in 1984 for evaluating CGSI concepts and for demonstrating simulation of coordinated multisensor displays (visual and FLIR).

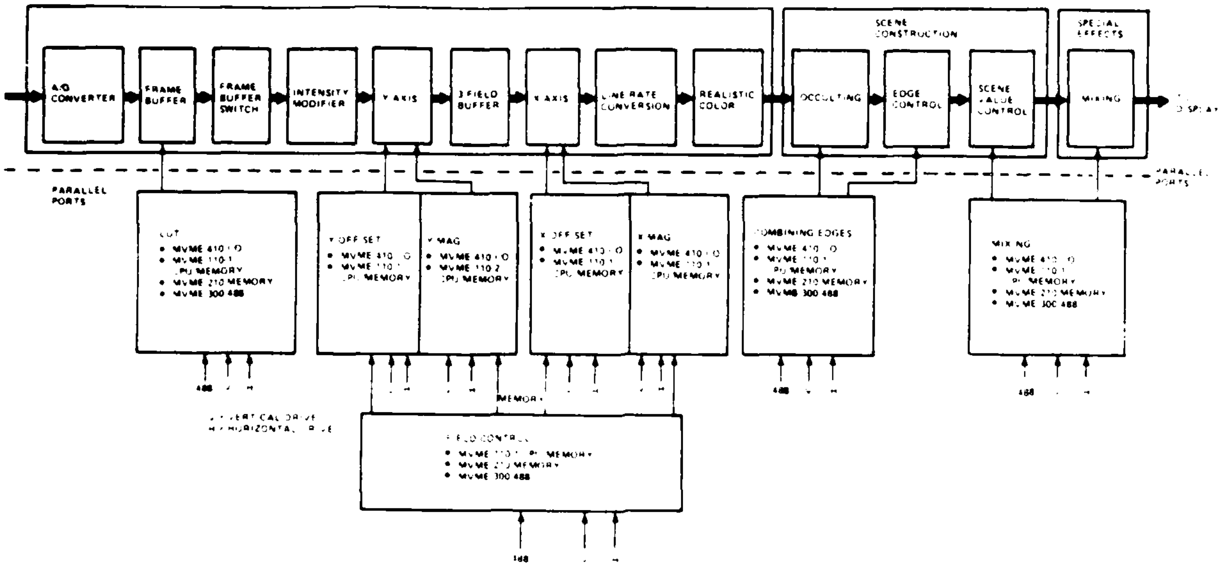


Fig. 16 Possible Control Hardware

Conclusions

Real time implementation of CGSI offers high potential payoffs in terms of meeting requirements for high fidelity, coordinated sensor simulation. The current program has triservice funding and is on schedule. Fabrication of a single pipeline is scheduled for completion in August 1983. At least two CGSI pipeline processors will be interfaced to NAVTRAEQUIPCEN visual technology research

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REAL-TIME CGSI-SINGLE PIPELINE PROCESSOR

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ABSTRACT

Non-real-time feasibility was demonstrated in 1982 for a hybrid visual/sensor simulation approach which merges two technologies, Computer Generated Imagery (CGI) and Computer Synthesized Imagery (CSI) to form Computer Generated Synthesized Imagery (CGSI). This approach holds promise as a cost-effective, attainable method of providing real-time, high detail imagery for visual and/or other sensors, such as FLIR. Because of the high potential payoff from the development of this hybrid approach, a current program is aimed at demonstrating feasibility of this CGSI technology in real-time. CGSI uses a modular set of building blocks which may be configured to meet specific training and simulation requirements. The pipeline processor is the major element in a CGSI system. The pipelines accept control commands from the Field of View (FOV)/Controller module and input video data containing objects from the data base. The Pipeline Processor then outputs transformed objects to the scene-construction module and special-effects module. To control risks, a single pipeline is being fabricated and tested before the remaining modules and additional pipelines are fabricated. The feasibility demonstration of a single pipeline is scheduled for September 1983. The results of these tests will be included in the oral presentation at the conference, but unfortunately will not be available in time to meet the publication deadline for the written paper. A description of the test procedure is included here.

INTRODUCTION

Requirements

Sophistication of weapons systems is growing at a rapid pace. This sophistication takes many forms including increased operational capability through use of multiple sensor systems including FLIR (Forward Looking Infrared), Imaging RADAR, LLLTV (Low Light Level TV) in combination with out-the-window visual. Proper task loading is often necessary to train operators and maintain skills in the use of sophisticated weapon systems. The arguments against using operational assets include cost and safety. There is, therefore, a need for increased fidelity through simulation. Current approaches in visual and sensor simulation are inadequate for tactical training. Modelboard systems lack the ability to provide multispectral imagery, weapons effects, moving targets, large gaming areas, and wide fields of view. Present Computer Generated Imagery Systems lack scene content to support this type of training.

This paper addresses a new technique being developed to increase visual and sensor simulation system fidelity and capability. Honeywell's Systems and Research Center is presently under contract to the Naval Training Equipment Center and the Army Project Manager for Training Devices to develop this increase in visual system capability and fidelity. The system under development will merge the attributes of an optical disc technology approach, Computer Synthesized Imagery (CSI), and Computer Generated Imagery (CGI). CSI provides high quality imagery, but does not provide free movement within a gaming area. CGI provides the necessary freedom of movement, but with highly stylized or cartoonish imagery. This hybrid concept of Computer Generated Synthesized Imagery (CGSI) utilizes optical disc photographic imagery (CSI) overlayed onto a CGI background. In addition to

ATTACHMENT 2

displaying individual objects in a scene, the system is capable of displaying groups of objects, imagery as seen from various sensors (e.g., FLIR and LLLTV) and adding smoke and other special effects. Initial non-real-time feasibility of this hybrid system has been demonstrated (1). Additional work is necessary and is being pursued to provide a real-time capability (i.e., a minimum update field rate of 60 Hz). Detailed design of a limited system was completed in April 1983 (2). CGSI uses a modular set of building blocks which may be configured to meet specific training and simulation requirements. The pipeline processor is the major element in a CGSI system. The pipeline processors change a stored image to scene conditions (screen coordinates) by changing image position, size, rotation, warp, and intensity. The Pipeline Processors then output transformed objects to the scene-construction module, pixel by pixel, based upon range. The pipelines will operate as single, large object processors; as multiple, small object processors; or as special effects processors.

A top-level system specification for each subsystem has been prepared. These specifications contained two key elements - performance and I/O requirements. After the specifications were reviewed and approved by both the Government and Honeywell, the detailed design effort began. Each subsystem was designed as a unit, with individualized hardware and software. This detailed design of the pipeline has been completed. The pipeline processor subsystem is the most complex subsystem. Therefore, to control risks, a single channel is being fabricated and tested before the remaining modules and additional pipelines are fabricated. The feasibility demonstration of a single pipeline was performed in early September 1983.

The CGSI system has been selected for a competitive fly-off to provide next generation visual and sensor simulation technology development for the U.S. Army. Technology being developed under this Army contract builds on a feasibility demonstration contract received from NAVTRAEQUIPCEN. This joint Navy/Army/Air Force effort will first demonstrate the real-time feasibility of the CGSI concept. The U.S. Army requirements are for the AH-64 Apache helicopter combat mission simulator. Visual requirements encompass weapons effects and delivery, wide field of view displays to support nap-of-the earth flight, multiple viewpoints, multiple sensors and multiple magnifications through a telescoping systems. The Apache requirements are felt to be one of the most demanding in the simulation industry today. The system described here could provide a capability to meet these requirements. The CGSI system has potential application for providing air-to-ground capability in the U.S. Navy's F/A-18 Hornet fighter/attack aircraft simulators and for filling low level contour training requirements on the CH-53 D/E and CH-46 helicopter simulators. One of the extremely attractive features of this approach is the potential for utilizing CGSI to retrofit existing CGI systems to increase performance. The Air Force's interest in this development results from the need for high fidelity simulation for air-to-ground attack missions. The Air Force Human Resource Laboratory (AFHRL) has provided funding support for the CGSI feasibility demonstration.

CGSI System Overview

The single pipeline is an integral part of the entire CGSI system. Therefore, a brief functional overview of a real-time CGSI system will be given here in order to provide understanding of the single pipeline in its proper context. Figure 1 is a functional overview of a real-time CGSI system. The functional blocks are separated into an off-line non-real-time data base construction module and a real-time processing system. A brief description of each module follows.

The data base consists of two very different types of data - the object library and the gaming area. The object library contains images of objects and surfaces in different spectral bands, and transmissivity masks of special effects. The gaming area data base provides the information necessary for placing the contents of the object library in the gaming area. The objects in the library may be either stationary or capable of movement. The vehicle simulation computations determine the locations and viewing

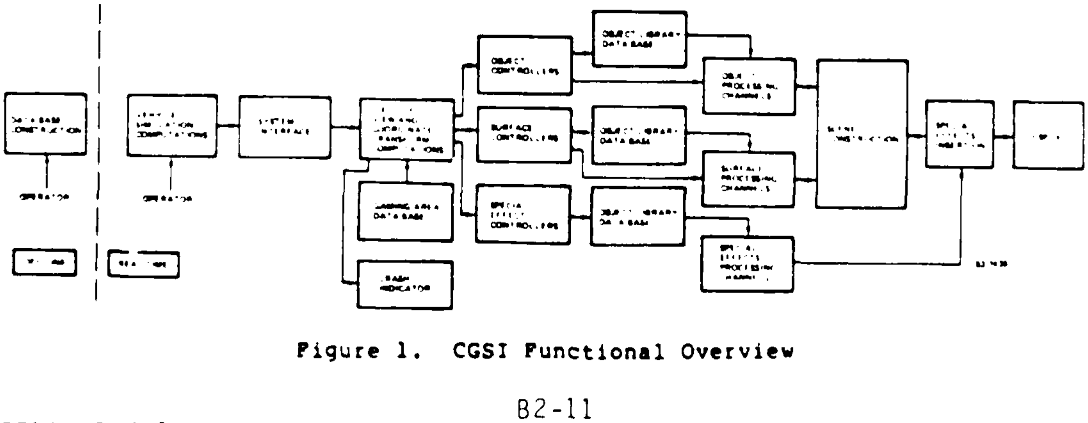

Figure 1. CGSI Functional Overview

ATTACHMENT 2

direction of the visual or sensor system for the primary vehicle. The FOV processor determines the presence of objects, surfaces, and special effects in the scene under construction. The output of a transformation matrix converts the real-world coordinates to screen coordinates. The controllers fan out and process the control functions generated during the FOV computation. The processed control functions are passed to the object/surface/special effects processing channels. The object, surface, special effects (OSSE) library stores the images used to construct a scene. The controllers command the selected images which are passed to the processing channels. The individual processing channel pipelines process one object, surface or special effect per channel. All the processing channels operate in an identical manner. The object, surface, special effect channels change a stored image (normal perspective) to scene conditions (screen coordinates) by changing image, position, size, rotation and warp. Image intensity is modified based upon range and object type. The scene construction module takes the individual image from each processing channel, separates the image from the background, and assembles the scene based upon range. The high frequency edges generated by assembling a scene from individual images are smoothed, matching edge and internal frequencies. The translucent special effects are added after the generation of the scene. The special effects module adds the special effects based upon range. Special effects, such as smoke or dust, may occur ahead of or behind images in the scene. The intensity masks are stored in the object library and processed in the special effects processing channel.

OSSE Processing Channels (Pipelines)

In this section, the functional overview, shown in Figure 1, is expanded to provide a generic hardware overview for a single pipeline and scene construction and special effect components (Figure 2). The system is modular; a small system may contain only several OSSE processors and a large system may contain several hundred OSSE processors. It is the intent of this design to allow the system to produce any type of imagery, visual, IR, MMW (Millimeter Waves), SAR (Synthetic Aperture Radar), radar, etc. Current funding includes simulation of visual and IR imagery.

Each object, stored group of objects, surface or special effect is individually processed by an OSSE processor and used to construct a scene in the scene construction module and special effects module. Depending on the size of an OSSE image, the OSSE processors handle from 1 to 16 OSSEs per channel. In this section the path of an image (one full image or up to 16 small images) will be traced from the image storage media to the image display subsystem. The processing of the image

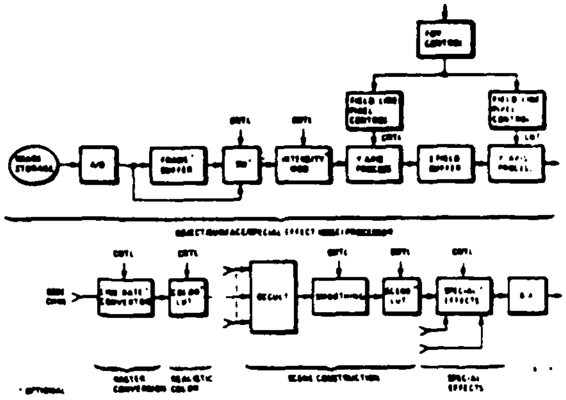

Figure 2. CGSI Configuration Elements

during its flow through the pipeline is under the control of a Field of View (FOV) controller. All OSSEs are processed in the same manner at the beginning. Depending on the function, major changes occur in the scene construction modules and special effects modules. Nontranslucent objects and surfaces (trees, rocks, bushes, tanks, etc.) are combined in the scene construction module. Realistic color or true color can be applied. Realistic color is generated via lookup tables and uses one pipeline, while true color uses three pipelines, one each for red, green and blue.

A/D Conversion. A high speed A/D module converts the analog video imagery to digital data. The module operates near 8 MHz and provides 8-bit, or 256 gray shade, output.

Frame Buffer. The frame buffer is controlled by the OSSE controller; it is used to store images that are not changing. This includes distant 2D objects and all surfaces and special effects. The warping process may compress data resulting in loss of resolution in the transmitted imagery if the image is rotated beyond 50 or 60 degrees. To limit rotations to + 45 degrees, a high speed memory design is used which can be accessed in both the X and Y axis. As a result, one image may be rotated a full 360 degrees without degradation through line and column memory access.

Frame Buffer Switch. The frame buffer switch allows the imagery to be held in the frame buffer for repeated use of 2D objects, surfaces and special effects. After an OSSE is stored in the frame buffer, the optical disc may be used to apply imagery to other channels. For dynamic 3D objects, the frame buffer allows the imagery to be taken directly from the optical disc without any delays. The frame buffer switch is controlled by the OSSE controller.

Intensity Modifier. The intensity modifier modifies the intensity of a scene in both global and local manners. Global changes use a LUT. As an example, these changes may be associated with range; that is, an object at a distance is more saturated and bluer than the same object at a very short range. Local modifiers multiply, on a real-time basis, each image pixel by an LUT value. The LUTs contents are a function of position within the frame. The intensity modifier introduces only pixel delays.

Y Axis Processing. The algorithm for distorting an object operates in two passes. Before explaining the Y axis functions, an overview of the warping function is presented. The warping algorithm contained in the pipeline operates in two passes; first the Y axis and then the X axis. The field microprocessor determines the offset (starting location), the magnification (change in line length) of the first line in each axis and selects the field memory buffers. The line microprocessor determines the delta offset and delta magnification of each line. The field microprocessor operates in a 16 millisecond cycle and the line microprocesor in a 63 microsecond cycle. The pixel processors operate on the pixel streams in a 100 nanosecond cycle or 10 MHz. During the first pass of the Y axis, each line in the row may be distorted in one or more of the following manners: Linear, perspective, curved, lens correction or multi-object (2).

Three Field Buffer. The three field buffer allows the Y axis processed image to be read into two field buffers, one for odd pixels and one for even pixels. The third field buffer allows either odd or even fields to be processed in the X axis processor.

X Axis Processing. The techniques used in the X axis could be identical to those used in the Y axis which includes the following functions: Linear, Perspective, Curved, Lens Correction, and Multi-Objects. In addition, for potential applications where perspective distortions in the real-world are not identical in the X and Y axis, the X axis processing could use algorithms which differ from the algorithms used in the Y axis. This case could occur with dome projection display systems or Synthetic Aperture Radar (SAR) imaging systems.

Line Rate Converter and Synchronizer. If the system requires other than 525 line video, a line rate converter changes the line rate of 525 lines to, for example, 875 or 1024 lines by changing the pixel clock rate. The line rate converter does not add lines or pixels; it only changes the rate at which the pixels are clocked in and out. In converting a 525 line system to 1024 line, for example, only 1/4 of the 1024 system is covered by a single 525 line input. The line rate converter is a first-in/first-out buffer (FIFO) that synchronized and positions the 525 line, 10 MHz imagery to and within the 1024 line, 40 MHz imagery.

Realistic Color. The CGSI approach has been developed to provide monochrome; realistic color; or full, true-color capability (See Figure 3). True color is provided through the creation of three spectrally distinct data bases - each full-color photograph is digitized and stored separately using optical quality red, green and blue filters. When a full color image is displayed, the red, green and blue object images are independently processed and delivered to the red, green and blue channels of the color display system used. One can see that full color is bought for a price: three times as many processing channels are required relative to the number needed to generate a monochromatic version (e.g., IR) of the same object image. Near-perfect color is achievable in a much more economical manner. Most OSSEs contain only shades of one or two colors; i.e., consider green leaves, brown branches, blue water, camouflaged targets. Look-up table manipulation techniques permit the generation of realistic (as opposed to true) object and surface color on the basis of mapped gray-shade imagery. The realistic color approach allows the CGSI system to generate terrain, vegetation and object colors with one-third the processing required. To obtain realistic color, each object is stored as a spectrally mapped image. Associated with each image is a red, green and blue LUT conversion that assigns up to 256 colors to gray shade levels of the image. The 256 colors that are achievable may be 256 shades of one hue - for example, shades of green to create a high fidelity color image of a bush - or 256 distinct hues. The process is thus precisely controllable, and provides adequate color capability for combat mission training simulations.

SINGLE PIPELINE TEST PROCEDURE

A single CGSI pipeline design has been completed as described above. The feasibility demonstration is scheduled for September 1983. A test plan has been developed to verify the operation of this single pipeline and will be described here. The objectives of this demonstration are to verify the speed and accuracy of a single pipeline, to provide contractor in-plant testing of a single-pipeline, and to provide real-time warping of 2D objects and 3D objects for both the visual and IR spectral regions. Figure 4 gives a system block diagram for the single pipeline feasibility demonstration.

Measurements of speed will include both throughput lag and update rate. Figure 5 gives the nominal design timing for the CGSI systems. Throughput lag (transport time) is defined as the time between the receipt of positional informa-

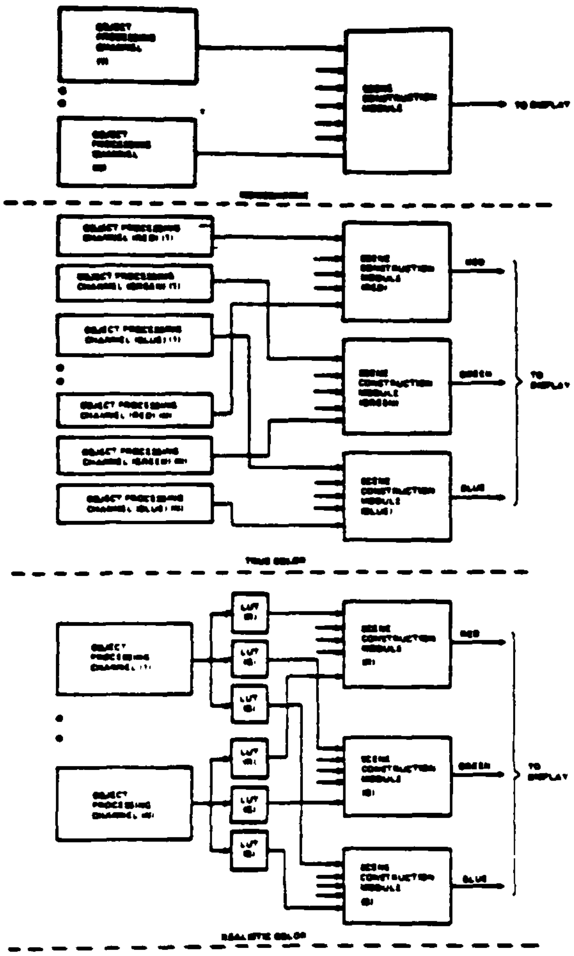

Figure 3. Color Hardware Configuration

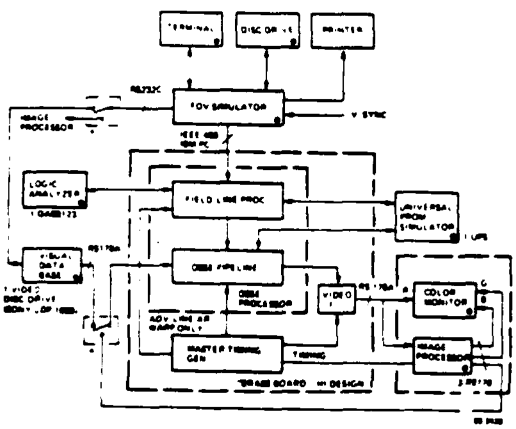

Figure 4. Single Pipeline Feasibility Demonstration

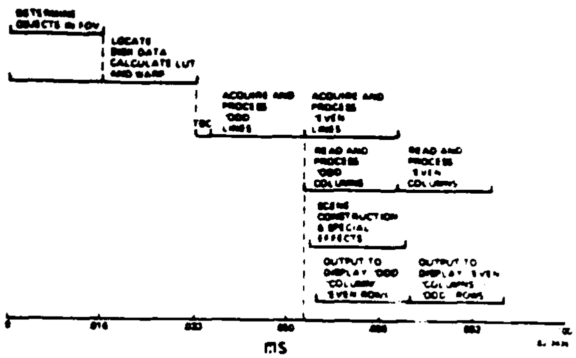

Figure 5. CGSI System Timing

tion from the vehicle simulation computer to the comple tion of the picture scan. Based on use of a specific test pattern, the delay from receipt of positional change information at the FOV computer to a change in output pixel value will be measured with a logic analyzer. Update rate is defined as the rate at which vehicular position may be changed. The design target update rate is 60 Hz. The operator will start the simu lation, causing the object to be displayed and move. Motion will occur because the FOV simulator outputs coordinates to the "pipeline" via the IEEE 488 interface at a 60 Hz rate. Delta values will be applied at each update by the simulation program to make the object move on the screen. Proper rate of motion will be verified by having the image processor sample frames out of the pipeline. These frames will then be analyzed off-line to verify that the pixel(s) are in the expected location(s) for the particular frame sample times.

Measurements of accuracy will include both measurements of screen location and timing. Screen location is defined as the absolute location of the object within the FOV as expected from commands transmitted to pipeline by the FOV computer. The test object will be translated in x,y, magnified, compressed, and rotated independently and in combination. The output of the pipeline is fed back into the image processor (See Figure 4). The image processor will enable non-realtime simulated imagery to be compared to real time pipeline imagery such that the monitor will display the object in three colors as follows: R=pipeline modified object, G=image processor modified object, B=background. The image processor and trackball will be used in combination to find differences between these images. Differences will also show up obviously as yellow on the color monitor. All differences shall involve 1 pixel or less. The timing of an object relative to the horizontal sync signal shall be controlled to

ensure object to object alignment at the scene construction module. The operator shall select an object which consists of a single pixel located in a known time slot on a known line. An oscilloscope shall be used on the pipeline output video to measure the location of the single output pixel relative to the line sync and the master sync.

The image stability will be tested. Image stability is defined as the constant location of an object from frame to frame in time. The operator will select an object to be sent through the pipeline. The image processor will be used to periodically sample a group of three frames. The image processor will be used off-line from the test with the pipeline to measure the location of the pixel matrix in each sample frame. The matrix location shall vary by no more than +/-1 pixel from the average (nominal) location across all of the sample frames. In addition to the above quantative tests, the following qualitative demonstrations will be observed. The image quality shall be photographic quality with minimum degradation resulting from processing. The capability of warping/displaying 2D and 3D objects for both visual and IR will be observed. The capability to interface the pipeline to a video disc player will be demonstrated. Realistic motion of objects will be assessed.

SOURCE OF DIGITIZED IMAGERY FOR A SINGLE PIPELINE

A point which may seem obvious to some, but is worthy of emphasis, is that a single pipeline can process any type of digitized data. It is immaterial what region of the spectrum (visual, IR, RADAR, MMW) is represented by the imagery or what the original source of the imagery was (real-world object, physical model of object, non-real-time CGI).

Current funding provides for simulation of visual and FLIR using the CGSI pipelines. Qualitative analysis indicates that other imaging sensors such as SAR and MMW could also be handled by CGSI pipelines.

Figure 6 emphasizes the fact that the source of the digitized imagery is variable. The CGSI pipeline can warp and properly inset any digitized image into a

Figure 6. CGSI Composite With Different Image Sources

scene. Figure 6 is a CGSI synthesized composite scene which illustrates three alternatives. It shows a real helicopter image which has been properly inserted into the mid-ground of a forest scene. It is obvious that in the real-world, it will not always be possible to photograph target objects at close range from various aspect angles. One alternative is illustrated in the foreground. A model tank has been constructed, photographed, digitized and properly inserted into this same scene. In addition, computers are capable of generating highly detailed, realistic objects in non-real-time. This non-real-time CGI (computer generated imagery) could provide input to the CGSI pipelines as illustrated in the sky. The fixed wing aircraft is a non-real-time CGI image. In some cases, non-real-time CGI may provide a viable alternative for feeding a CGSI pipeline.

The critical point to emphasize here is that the single CGSI pipeline has been designed to be a highly flexible, modular building block for providing high fidelity visual and sensor simulation to meet a wide range of training simulation requirements.

MULTIPLE PIPELINE CONFIGURATIONS

As the CGSI concept moves into physical realization in a real-time demonstration, its application to real-time training visual and sensor systems become practical and advantageous. Such application is clearly warranted whenever high object fidelity or high data base flexibility is required, although other instances of favorable application exist.

This CGSI development is unique for a research effort. Critical considerations are being designed into the system from the ground up. These include reliability, maintainability, integrated logistics support as well as development, production, and support cost issues. CGSI is being designed as a system that works and will continue to work in a cost effective manner in an actual training environment. This is an extremely ambitious undertaking. However, if these critical considerations are not designed into the system initially, extensive redesign would be necessary in order to provide a capability for answering real training problems in the field.

<u>System Analysis</u>. Based upon the identified training mission requirements, CGSI systems configuration development becomes an iterative sequence of refinements/trade-offs involving the various CGSI building blocks previously described. The elements to be considered in addition to the training mission requirements are considerations of reliability, maintainability, integrated logistics support as well as development, production and support cost issues. Table 1 gives a listing of CGSI system building blocks and the configuration rules for developing a large CGSI system.

Table 1. Configuring a CGSI System from Building Blocks

o	SELECT DATA SOURCE	1) VIDEO DISK 2) WRITE-ONCE VIDEO DISK 3) MAGNETIC STORAGE 4) GRAPHICS
o	SELECT PROCESSOR	1) OSSE 2) OSEE/W/TRUE PERSPECTIVE 3) GRAPHICS 4) CGI
o	MAKE 525 OR HIGHER RESOLUTION DECISION.	1) 10 MHZ, OR 2) 40 MHZ FOLLOW-ON CARDS (ADD LINE RATE CONVERTER)
o	MAKE B/W, TRUE VS REALISTIC COLOR DECISION	(ADD COLOR LOCK-UP TABLE (LUT))
o	IS ITERATIVE SCENE DEVELOPMENT REQUIRED?	(ADD ITERATIVE RANGE AND IMAGE MEMORIES)
o	IS CHANNEL IR, VISUAL B/W, OR VISUAL COLOR?	1) IR SMOOTHING, VISUAL SMOOTHING
o	SELECT NUMBER OF SPECIAL EFFECTS CHANNELS.	
o	CONFIGURE TIMING CONTROL, FIRMWARE, AND SOFTWARE TO MATCH.	

These trade-offs take two forms: 1) balancing training effectiveness versus cost, and 2) trading off technically limiting parameters to achieve optimum system performance. The training effectiveness trades are primarily related to number of OSSE channels required. When the training mission analysis has defined the characteristics and count of the objects to be presented, an obvious but simplistic approach to configuration would be to provide a channel per object. This, however, would produce an excessively large and costly system when alternatives exist with either no or minimal training impact. The number of OSSE channels required can be traded off against: 1) Off-line development of composite scene views (clusters), 2) On-line iterative composite scene construction, 3) Area of Interest (AOI) displays, multiple resolution displays, 4) Realistic versus true color. (True color channels can be mixed with realistic channels if required for selected critical objects), 5) Training Cue Fidelity (This trade area is the most subjective but provides the most opportunity for ingenuity of approach), 6) Availability (For very large visual systems, system reliability becomes a training issue because of significant failure rates and/or extended repair times). Numerous alternative implementations and trades exist beyond these six in configuring a CGSI system. Trade alternatives exist in the purely technical realm also. An example is transport delay/update time. While the nominal transport delay of an OSSE process is related to a 512 X 512 image area, smaller image definition (say 256 X 256) will yield shorter transport delays by reducing the field processing time.

As an example, a CGSI configuration for a small visual system could provide potential applications for periscope training or hand-held missile or gunnery applications. Figure 7 shows a non-real-time CGSI scene of a view thru a periscope which could be provided in real-time by a small CGSI configuration. Figure 8 depicts a CGSI configuration capable of providing this image. Figure 9 shows a non-real-time CGSI scene of a AH-64 flying among the trees which could be provided in real-time by a large, robust CGSI configuration. Figure 10 depicts a CGSI configuration capable of providing this imagery level with all sensors supported for team training.

<u>Design</u>. The system analysis trades result in specific design requirements related to configuration. In assembling the required configuration from the CGSI building blocks, the modularity and configurability of the CGSI components together with standardized inter-card and inter-channel interface minimize new design. Correlated hardware, software and firmware components also ease the configuration process. Despite this modularity, every new application will require unique responses.

<u>Life Cycle Support</u>. A key element of any trainer application is the life cycle support requirements of the system. This normally includes maintenance and spare issues. Increasingly, especially for software intensive applications, this has meant the enhancement or redirection of a trainer for new training requirements related to new tactics, new equipment (Avionics, Visionic Weapons Systems), and new personnel qualifications. Historically, visual systems have had extensive data base maintenance costs and infrequent but extensive hardware/software upgrades. CGSI promises significant improvements in all of these areas: 1) Maintenance - On-line BITE, and extensive isolation are included. 2) Spares - Few card types minimize replacement cost as well as lowering stores inventory. 3) New Training Requirements - Common building blocks permit multiple use of CGSI systems and

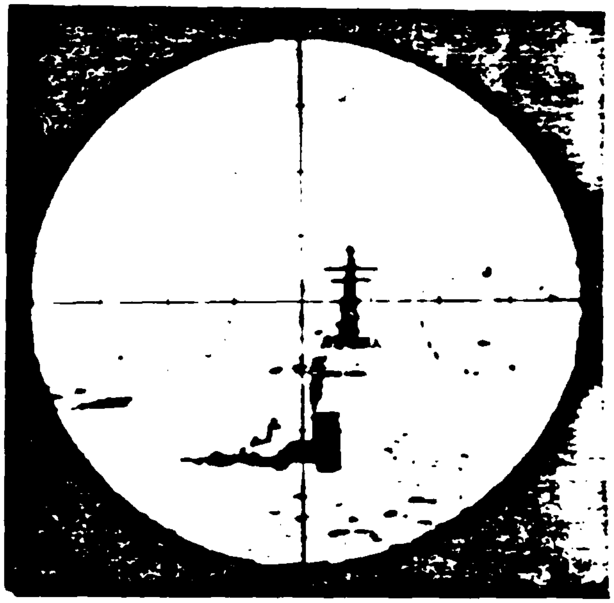

Figure 7. CGSI Simulated Periscope Image

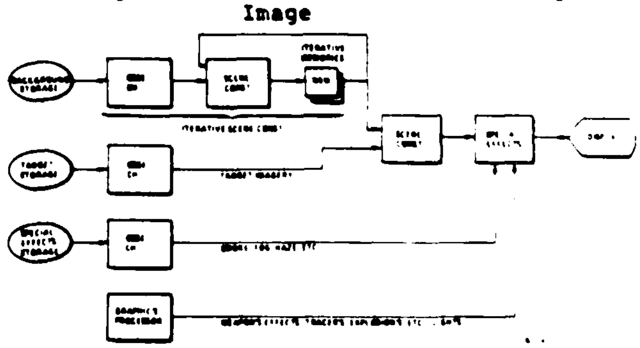

Figure 8. Small CGSI Configuration

Figure 9. CGSI AH-64 Simulated Image

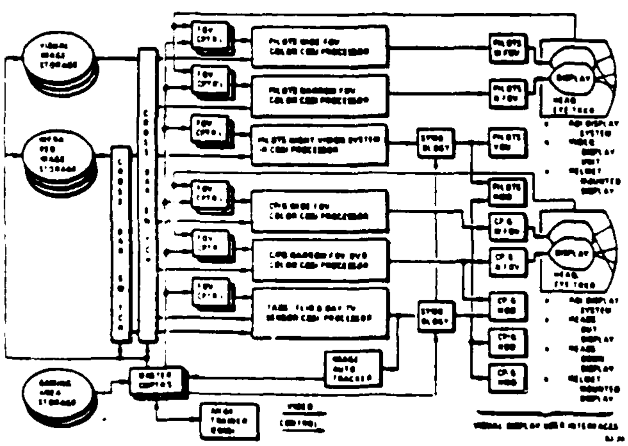

Figure 10. Large CGSI Configuration

incremental expansion to higher fidelity simulation. 4) Data Base Maintenance - Rapid specific area simulations through Defense Mapping Agency (DMA) data and straight forward data definition. Rapid target compliment updates are accomplished through actual imagery equipment for replacement applications or the addition of similar like components for new applications.

Adaptability. Beyond the new visual trainer application, CGSI is adaptable to a wide range of trainer and simulator applications. 1) Stimulators - Stimulation of operational equipment or equipment under evaluation is made possible by insertion of high fidelity video stream data to trackers. 2) Part Task Trainers - A modular approach provides limited simulation applications for limited training

goals. 3) Team tactics trainers - Systems providing coordination training involving multiple vehicles and/or ground personnel are easily configured. 4) Existing CGI visual retrofit - Typical CGI systems of today exhibit inadequate target fidelity and very limited background fidelity or a serious compromise of both. CGSI can be used to supplement such systems requiring higher fidelity.

CONCLUSION

CGSI is a viable approach to visual and/or sensor simulation in multiple applications ranging from the very small to the extremely large. It is clearly warranted when high object fidelity and/or high data base flexibility is required. It can readily support multiple sensors in integrated operation including special effects from multiple viewpoints. It is capable of providing specific area simulations with full freedom of motion for both own ship friendly vehicle and hostile targets, and supports Trackers and Weapons, with high Gaming area flexibility and large environment variations. The next critical milestone in this CGSI development is the demonstration of a limited multiple pipeline configuration (4 pipelines) integrated with all of the modules outlined in the block diagram in Figure 1. This demonstration is scheduled for April 1984.

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ATTACHMENT 3

HELMET MOUNTED LASER PROJECTOR

1.0 ABSTRACT

A display system for flight simulation is described. The system employes optics mounted on the pilot's helmet to project a scene onto a retro-reflecting screen. It is driven by two Computer Image Generation (CIG) channels, one providing a wide-angle display while the other provides a high-resolution, eye-directed inset. The concept uses both head tracking and eye tracking to provide an effectively unlimited field of view with high resolution at low cost.

1.1 INTRODUCTION

The Advanced Simulation Concepts Laboratory of the Naval Training Equipment Center is pursuing an exploratory development program to design a visual simulation system and analyze the feasibility of fabrication. The system will be designed for use in the Navy Visual Technology Research Simulator (VTRS) with new hardware intended to interface with existing VTRS equipment.

The system will have part of the display projection optics mounted on the pilot's helmet and be fully visually coupled, demanding use of both head-tracking and eye-tracking techniques. Optical design for the display system is currently well advanced and experiements have been carried out in both head- and eye-tracking. This paper describes and discusses the evolution of the basic approach taken, and outlines the present design and the results of experiments.

The system performance objectives include an effective total field of view which is limited only by cockpit structure and the pilot's normal freedom of movement within the cockpit. Associated wtih this large field of view, typically 8 steradians, the target resolution is 3.3 arc minutes per line pair. The scene is to be presented without noticeable seams or discontinuities, and is to be available, without distortion, to two or more subjects in the same simulated aircraft. The method proposed has potential for presenting a collimated picture and eventually a three-dimensional picture.

1.2 DESIGN CONCEPTS

1.2.1 Visual Coupling

The very demanding specification is achievable in principle by many different approaches. But generally, the cost of attaining the basic objectives - very wide field, high resolution and multiple-user operation - would be considered excessive using available display technology. In general, the wide angle and high resolution objectives together demand a powerful pixel generation capability, leading to multiple projectors and very broad electronic bandwidths, and to multiplied cost of computer image generation or other video generation systems. The requirement for multiple-user operation, taken together with the very large field angles, would in general require very costly collimation optics, or else duplication of the entire simulation apparatus (with large actual separation of the users).

The approach taken is based on matching the display system performance, in terms of field of view and resolution, to the visual performance parameters of the observer's eyes. The observer's capability to perceive high detail at any instant is restricted to a relatively small area of interest corresponding to his foveal vision. The size of the instantaneous field in which he can perceive any visual information at all is less than the field available to the observer through head and body movements. By providing a display system which presents high detail imagery only where the observer is looking, with an instantaneous field which matches his instantaneous field, the observer will perceive the display as having high detail imagery throughout his total available field. But the total burden on the display system, in terms of computed and resolved pixels in each frame, is very usefully limited. For these reasons, there has been a strong thrust in recent years to visually coupled system of different kinds, in which the projected scene or a high-detail insert follows the observer's head- or eye-direction.

1.2.2 NTEC System Goals

Figure 1 shows an artists' concept of the NTEC display looking over the observer's shoulder. The display has an eye directed area of interest (AOI) field which is a nominal 1000 television line (TVL) raster driven by a dedicated CIG channel and a head directed instantaneous field of view (IFOV) which is a second nominal 1000 TVL raster driven by a second CIG channel. The system is largely compatible with the existing VTRS computer image generator (Reference 1.). Table 1 lists the system performance goals chosen for the design.

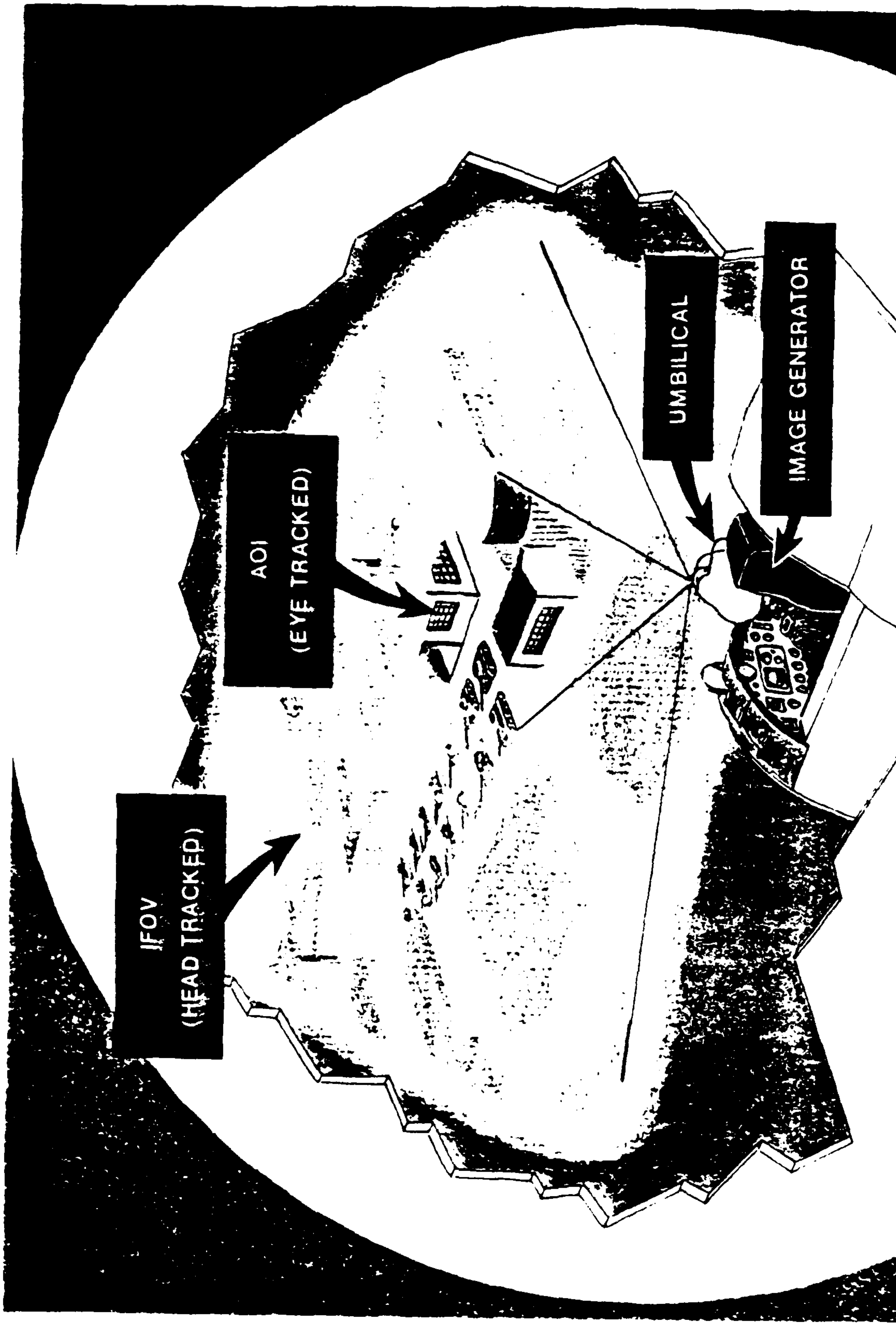


FIGURE 1
PILOT HELMET MOUNTED DISPLAY

ATTACHMENT 3

The VTRS CIG has a capability of providing 2,000 potentially visible edges distributed between the two display rasters. If this capacity is shared equally between the displays, the scene complexity or edge density will be approximately twenty times higher in the AOI channel relative to the IFOV channel.

TABLE I. SYSTEM PERFORMANCE GOALS

Apparent Field of View	Restricted only by cockpit structure
Instantaneous Field of View	145° diagonal
Area of Interest	36° diagonal
Apparent Resolution	3.3 arc min/TV line pair
AOI Resolution	3.3 arc min/TV line pair - on axis
IFOV Resolution	13 arc min/TV line pair - on axis
Luminance	10 Foot Lamberts (Highlight)
Color	Full
Contrast	30:1

1.2.3 Helmet Mounted Projector

The display configuration was developed from a Helmet-Mounted Laser Projector concept descibed in a contract report (Reference 2.) delivered by American Airlines and Redifon Simulation Ltd. Helmet-mounted optical systems commonly have small CRTs on which an image is generated and the optics project light into one or both of the user's eyes via mirrors or beam splitters located in front of the user's eyes. In the Redifon proposal, the scene is projected outward from the helmet onto a dome screen from an exit pupil located above the user's eyes. The screen is given a stronly retro-reflective coating so that a relatively large proportion of the projected light is reflected to the user. In order to achieve high brightness in the display over a wide angle, without mounting excessively heavy optics on the helmet, Redifon proposed to use a laser display system and a coherent fiber optic link to carry ligh to the helmet. The use of lasers permits high brightness across a wide projected field without requiring wide-aperture projection optics. The flexible fiber link permits the more massive optical components, including the lasers, modulators and line scanner, to be mounted at a remote location, off the helmet. The fiber link to helmet mounted optics is not a concept unique to Redifon, but Redifon has made the fiber link itself more viable by proposing to put a light-weight frame scanner on the helmet. This means that the optical fibers are required to transmit line images, rather than full

frame images; few fibers are required, with significant advantages in flexibility of the link and reduction of manufacturing difficulty.

The aspects of the Redifon concept described above have been retained in the NTEC development. In other respects the concept has been modified, mainly to reduce the likely cost and time required to build a working system.

Helmet mounting of projection optics generally has several advantages for visually coupled displays:

a. The display automatically rotates with the head-pointing direction.

b. There is no significant distortion due to rotation of the projector.

c. Good photometric efficiency is possible (with either direct projection into the eyes or outward projection onto a retro-reflecting screen).

d. Two or more subjects can use the same simulator cockpit without seeing distorted views of each other's head/eye directed scenes (cross-talk), and each can receive an undistorted scene image.

e. With binocular projection the technique has potential for effective collimation of the scene, and for 3-dimensional presentation (neither at present planned by NTEC).

1.2.4 Dome Screen

Projection outward from the helmet onto a screen, rather than projection directly into the pilot's eyes, was selected for these reasons:

a. It does not require beam splitters or any other hardware to be fixed immediately before the pilot's eyes thus obstructing a normal view of the cockpit interior.

b. It permits a very wide instantaneous field of view, comparable with the pilot's total field with head fixed, to be projected and viewed by both eyes.

c. It provides automatic and precise blanking of the projected outside-world scene at the cockpit outline, since the cockpit structure does not retro-reflect, without need for head position tracking or electornic raster blanking.

1.2.5 Head-Tracking Functions

Since the projected rasters rotate with the user's head, the view direction used to compute the scene must be updated at field rate to include head rotations. A

tracking device, measuring pitch, roll and yaw of the helmet with respect to the cockpit, must therefore be included in the visual simualtion system.

Errors in helmet attitude data transmitted to the CIG produce errors in location of the perceived scene. Inadequate precision can result in image jitter, low accuracy will produce image swimming, and inadequate response will cause the image to lag head movements.

Image lag due to CIG throughput delay can be compensated, since the error is known given fast head-tracker response, by offsetting the projected image rasters using optical deflectors.

1.2.6 Eye Direction Following Functions

The small AOI raster, with high reolution and high detail content, is required to be shifted, within the wide field of the helmet mounted projector, so that this area is always on the axis of the pilot's eyes.

Within the optical projection hardware, this requires provision of deflectors to shift the scene vertically and horizontally. Within the CIG system, it is necessary to provide corresponding shifts in computed locations of the AOI view window and raster. Data to determine the eye-following deflections must be provided by an eye attitude measuring system.

1.3 DISPLAY SYSTEM

Figure 2 shows a functional diagram of the display system.

Mounted off the helmet are lasers, intensity modulators and a line scanner. These components provide two intensity modulated line scan images, one for the AOI raster and one for the IFOV. The two line scan images are carried to the helmet-mounted components by two flexible coherent fiber optic bundles.

Mounted on top of the helmet are galvanometers driving flat mirrors. These provide frame scan and eye-following offsets of the projected rasters. The frame-scan and offsetting optics are followed by a compound projection lens system which relays the light to an exit pupil location in front of the user's forehead and projects the light outward toward the display screen providing the angular magnification required to fill a 145° instantaneous field.

The screen is a spherical dome surrounding the simulator cockpit giving the user a total field (with head and body movements) which is limited only by cockpit structure. The screen is coated with a retro-reflecting material.

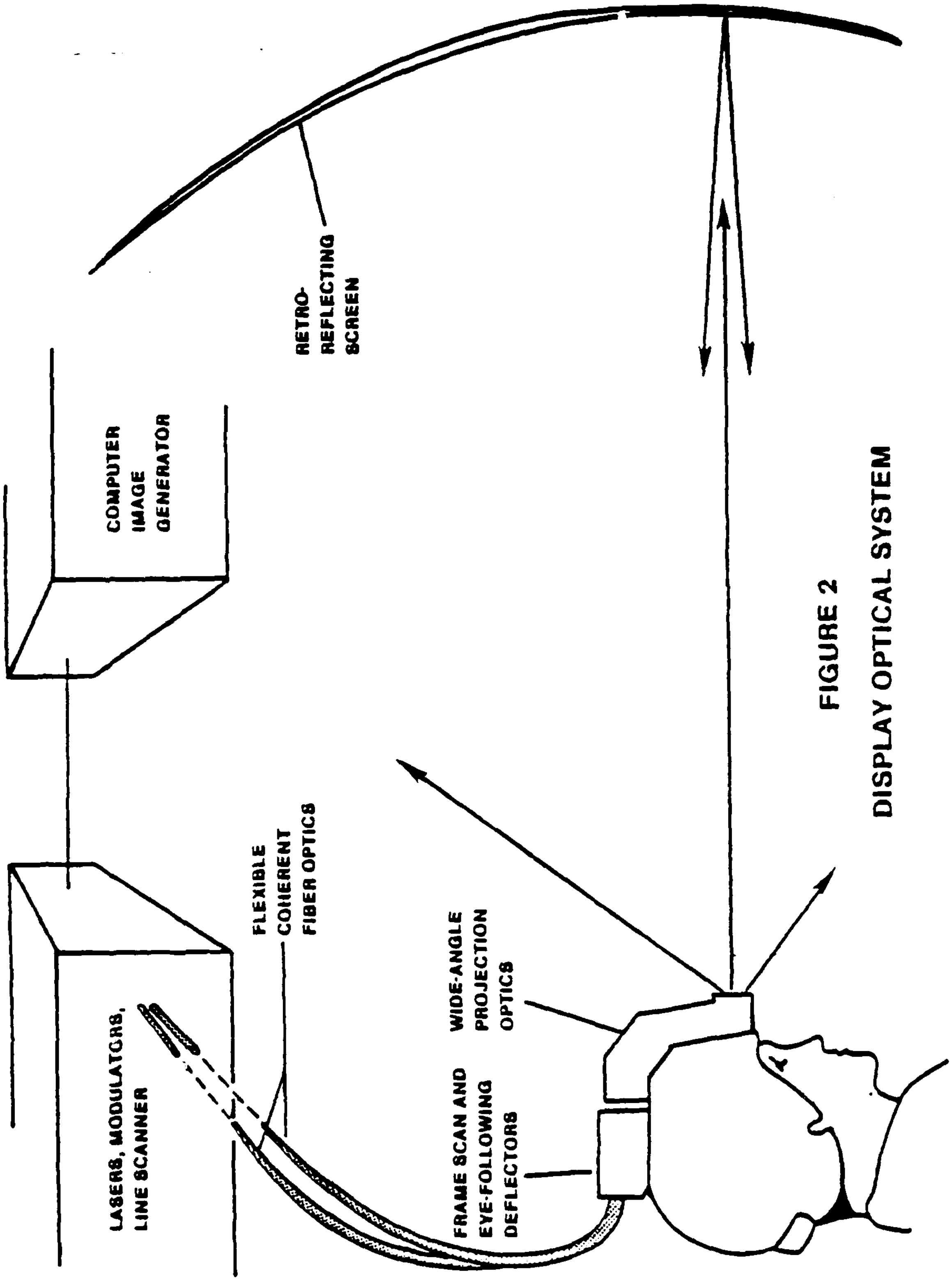


FIGURE 2
DISPLAY OPTICAL SYSTEM

ATTACHMENT 3

The CIG system has inputs from head-tracking and eye-tracking devices, not indicated in Figure 2. These inputs determine rotations of the view direction to follow head orientation, and computed offsets of the view window and raster to follow eye attitude. In addition to providing video signals to modulators and controlling simple line and frame scan functions, the CIG system controls offsets in the projected ratsers produced at helmet-mounted deflectors. These offsets are principally for eye following but also compensate for errors due to finite computational throughput time.

1.4 LASERS, MODULATORS AND LINE SCANNER

Figure 3 is a functional diagram of the optical system feeding the helmet-mounted projector.

The beam from an Argon ion laser, operated in all-lines output mode, is split into its separate wavelength components by a dispersive optical system. Part of the power at 514.5 nm is split off to provide a green beam, and power is a selected set of blue wavelengths is split off to provide a blue beam. Blue-green components, plus residual green power, are used to pump a Rhodamine 6G dye laser, which is tuned to output red light at wavelength 610 nm. Dispersive optics are used to recombine separate wave lengths assigned to the blue primary onto a single beam, and similarly to recombine the separate wavelengths assigned to pumping the dye. The Argon laser output power required to achieve a 10 f.l. display brightness is estimated, based on pessimistic assumptions, at 10W.

Red, green and blue beams are eachs plit in two for AOI and IFOV rasters, and the six separate beams are intensity modulated at acousto-optic modulators. These beams are then combined to give two full-color beams, which are then scanned at a common line scanner and imaged, separately, onto two coherent fiber optic bundles.

The line scanner is a rotating polygon having 24 facets, rotating at 76,725 rpm to give a line rate of 30,690 lines/second to both modulated full-color beams. The line scan images will be 10 mm long by 10 microns wide. Each image will fall on a single row of 1000, 10 micron, optical fibers. (The fiber bundles may, for maufacturing convenience and to allow some selection, have many rows of 1000 fibers each.) The maximum expected laser power density on the input end of the IFOV fiber bundle is 20 W/mm^2, which is within a factor 2 of a measured damage threshold. Therefore, tolerance to incident power is an important part of the fiber optic

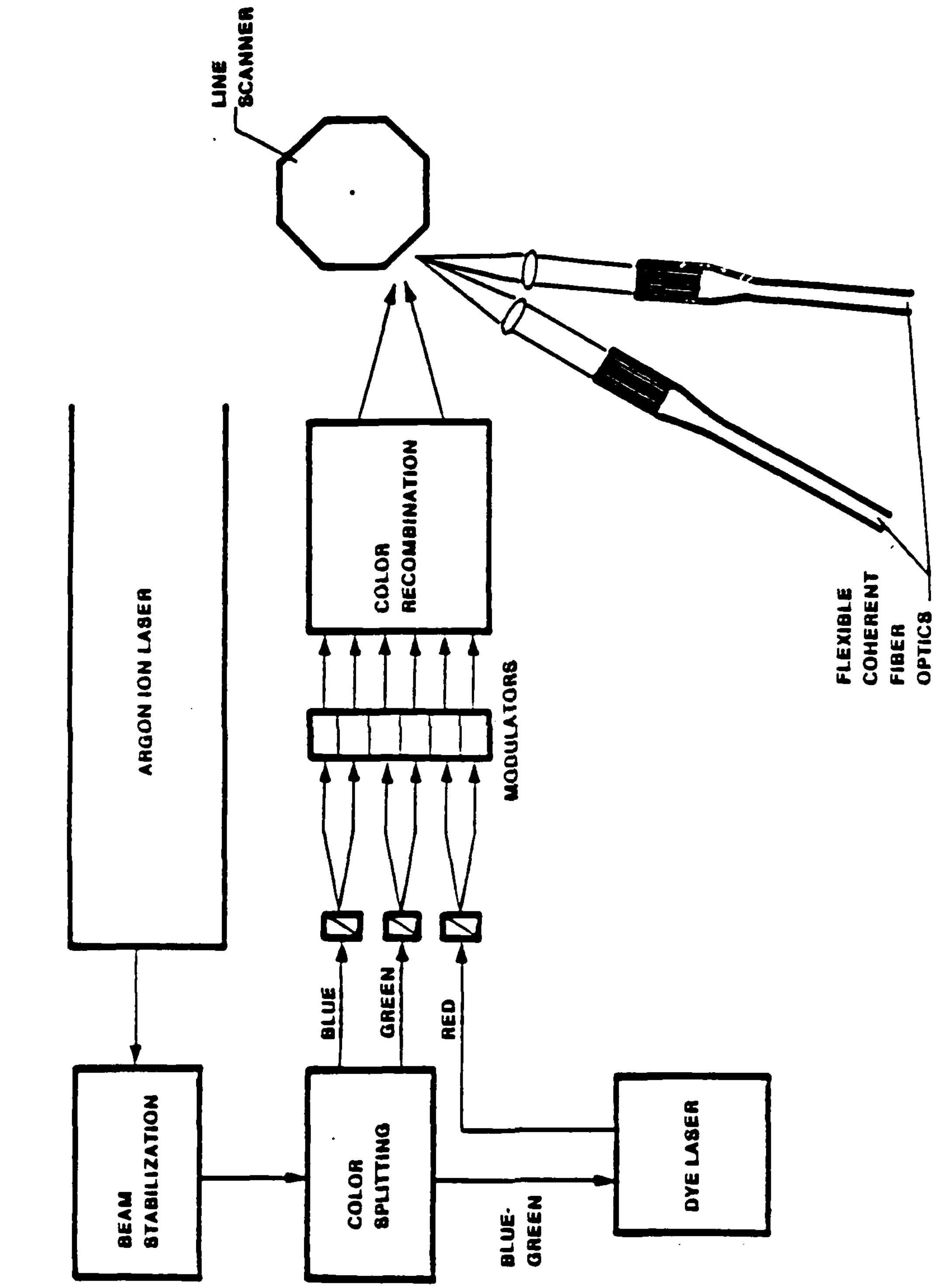


FIGURE 3
OFF - HELMET OPTICAL SYSTEM

ATTACHMENT 3

procurement specification. The fiber optic bundles will be approximately 9' long, permitting the lasers, etc., to be remote from the simulator cockpit.

1.5 HELMET-MOUNTED OPTICS

The design for optics mounted on the user's helmet is shown in Figures 4, and 5.

The helmet-mounted optics include mirror scanners driven by galvanometers, and the final wide-angle projection lens which directs the light outward to the display screen. The mirror scanners are used to generate frame scan for the two projected rasters, AOI and IFOV. They also provide a capability for controlled offset of the two rasters with respect to the axis of the helmet mounted projector lens. Light from the two line scan images, input by fiber optics, is first passed through a scanner subsystem which permits the two line scans to be shifted along their own lengths. This produces a line-direction shift of the projected rasters, normally a horizontal shift, which is used primarily for following horizontal eye rotations. After passing through relay lenses, the two beams are reflected at separate scanner mirrors mounted on the shaft of a single galvanometer so that the line offset mechanism shifts the two rasters together.

In each beam, the light path is folded at a narrow strip of flat mirror on a window located at a line scan image. The light is then recollimated by a spherical mirror and relayed onto the frame scanners, passing through the window.

Two flat mirrors, driven by separate galvanometers, provide frame scan and also combine the two beams on a common optical axis. The frame scanners provide controlled offset of the rasters in the frame scan direction, which is normally the vertical direction. The AOI beam is deflected at a single galvanometer-driven mirror, designated the AOI mirror, which produces the cyclic linear ramp scan required for the AOI raster. The IFOV beam is first deflected at a small galvanometer-driven mirror, designated the IFOV mirror, which generates cyclic linear ramp scan to produce 3/4 of the frame dimension for the IFOV raster. The IFOV beam then falls on the AOI mirror which adds frame scan to complete the IFOV raster.

The two beams are effectively combined at the small IFOV mirror. The IFOV beam is reflected from it, while the AOI beam, which has a larger diameter, passes around the mirror with partial obscuration by it.

Controlled offset of the rasters in the frame direction is provided by an offset only at the AOI mirror. Since both beams are deflected at this mirror, the two

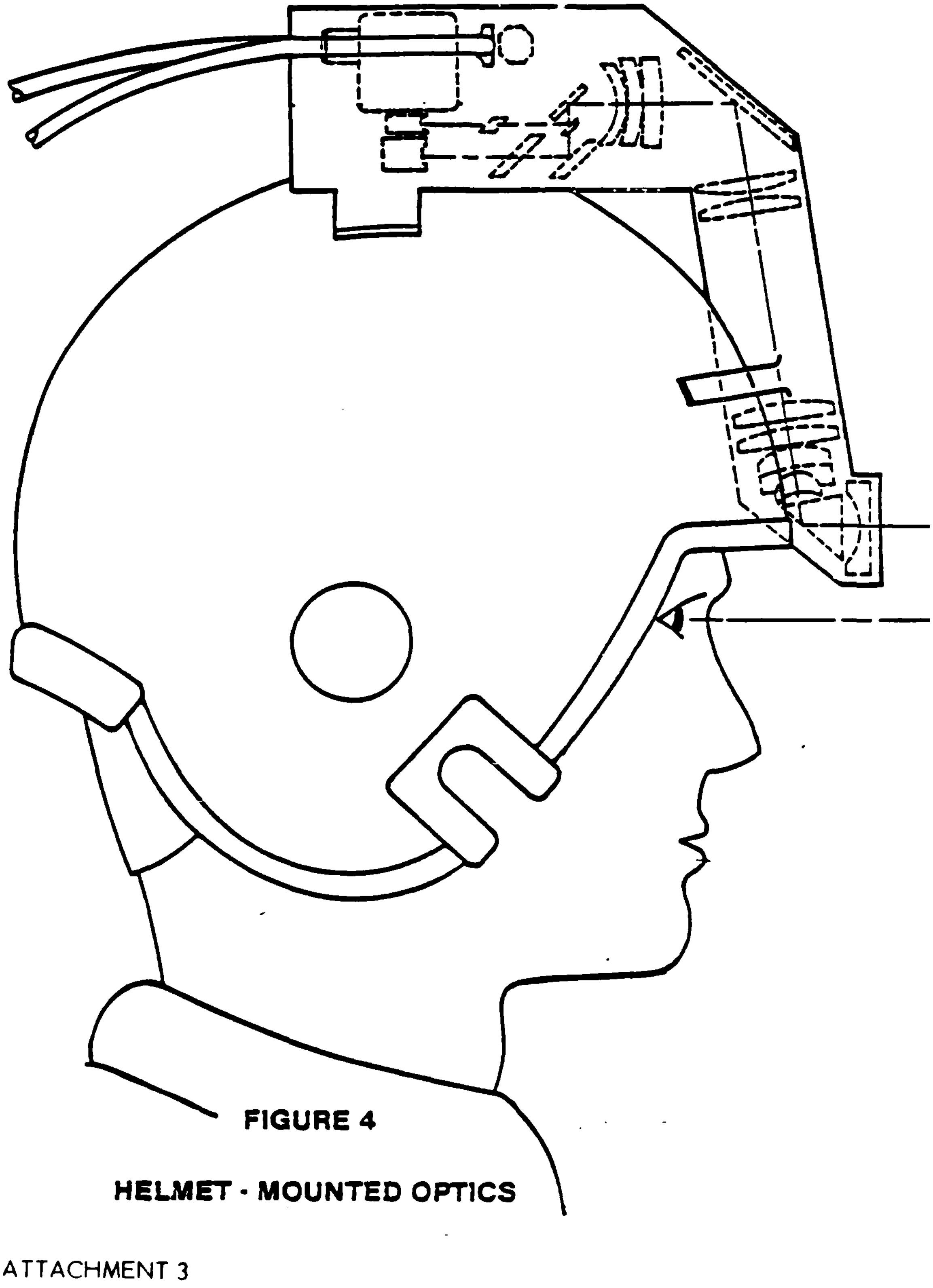
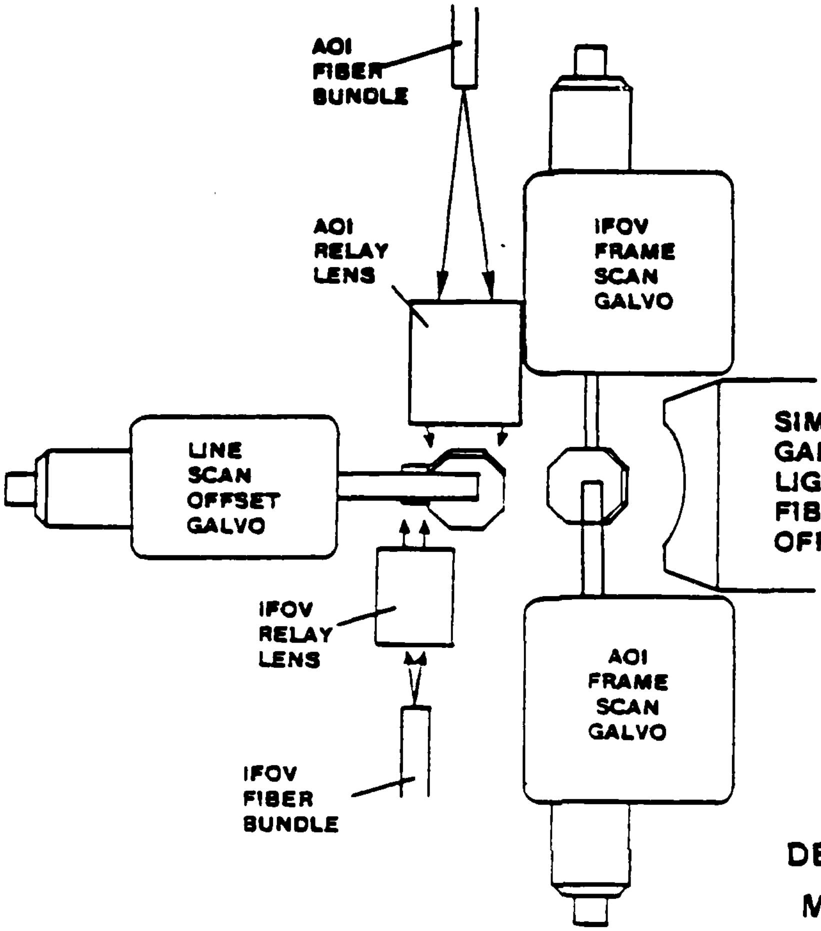


FIGURE 4

HELMET - MOUNTED OPTICS

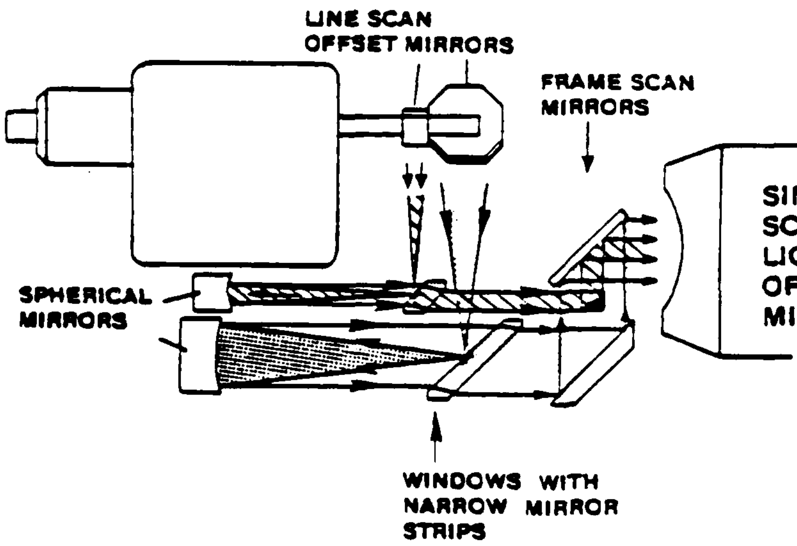
ATTACHMENT 3



SIMPLIFIED TOP VIEW-
GALVANOMETERS AND
LIGHT PATHS FROM
FIBERS TO LINE
OFFSET MIRRORS

FIGURE 5

DETAILS OF HELMET-MOUNTED OPTICS.



SIMPLIFIED SIDE VIEW-
SCANNING MIRRORS AND
LIGHT PATHS FROM LINE
OFFSET TO FRAME SCAN
MIRRORS

ATTACHMENT 3

rasters are deflected together. The offset is used primarily to follow vertical eye rotations.

The frame-scan and raster offsetting optics will be located on top of the pilot's helmet. The raster images generated at this point will have moderate field angles, AOI and IFOV line lengths being respectively 11° and 44°. Light emerging from the frame-scan system is relayed by a complex lens and mirror system to an exit pupil which will be located in front of the pilot's forehead, approximately 30 mm above his eye level and 70 mm forward of his eyes. The system will provide angular magnification and direct the combined raster images outward onto the display screen.

The final lenses will produce substantial pincushion distortion, corrected in CIG, which is useful in distributing resolution optimally across the projected field.

1.6 COCKPIT AND DISPLAY SCREEN

The display screen will be a ten foot radius dome, already available in the VTRS facility, coated with retro-reflecting material. The separation of the user's eyes from the projector exit pupil will be approximately three inches so that the screen surface will be required to provide reasonably uniform spread of light within 1.5° of the retro-reflective direciton. A photometric gain in excess of 1000 is in theory possible, given this requirement on beam spread, but the target figure for screen gain is 100, which is considered likely to be achieved.

Commercially available retro-reflecting screen materials have characteristics similar to the required material, but none is close enough, and therefore a special product is required. This development is currently underway through acontract with the University of Arizona Optical Sciences Center.

The method of projection, from a point a few inches from the user's eye-point, produces potential problems due to light falling on the cockpit structure. Internal surfaces of the cockpit will reflect low-brightness images of the projected scene and it is necesary to ensure that these images will not be noticable. This is done essentially by arranging that the photometric gain of the screen is very much higher than the gain of cockpit surfaces - in fact by three to four orders of magnitude - so that the relative brightness of the screen image is two to three orders higher than that of ghosts within the cockpit. The dim ghost images on the cockpit structure will normally not be visible against a background of ordinary internal cockpit lighting.

The wide-angle scene projected onto the screen will have sharp boundaries due to shadowing by cockpit structures. Shadows produced by the lower edges of

cockpit windows are not visible to the user, but shadows produced by window struts have been found, in simple experiments, to be very noticeable. The helmet-mounted projection technique is likely to be used only in simulator cockpits in which window struts are omitted.

Windows themselves will also be omitted to avoid possible specular reflection of projected light by the windows directly to the user, and care will be taken to avoid specular reflections to the pilot from cockpit instrument surfaces.

Use of the helmet mounted display will require some relatively minor alterations to the simulator heads-up display. The heads-up display beam combiner will be made as thin as possible, and its reflection coefficient reduced, so that it will not produce an objectionable displacement or shadow in the forward area of the projected scene. The brightness of display light reflected to the pilot from the heads-up display lens and CRT will be low compared with the brightness of the screen image. The CRT location will be shifted so that its virtual image falls at the screen distance.

1.7 SOME DEVELOPMENT PROBLEMS

In general, the approach taken in design of the display system has been chosen to reduce procurement problems to a minimum so that a visually coupled system, using helmet mounting, can be assessed as soon as possible and at relatively low cost.

Given the basic idea proposed by American Airlines and Redifon, potentially severe development problem areas include: The fiber optic link, the helmet-mounted frame scanner and the retro-reflective screen. The specification on the fiber optics is relaxed considerably by allowing the helmet-mounted system to be relatively complex. In particular, the length of the AOI line image to be carried by the fibers is minimized by locating the line scan offsetting sytem on the helmet; and the output end configuration of the fiber bundles is simplified by use of a relatively complex flat-field lens system on the helmet. The complex lens system, by providing angular magnification, also reduces the specification on frame scanners so that existing galvanometers can be used. The complexity of the helmet-mounted projection system which is evolved on these lines might make a binocular system, with separate optics for each of the user's eyes, prohibitively bulky. Therefore, a decision was made not to attempt a binocular arrangement, and to forego effective binocular collimation and immediate potential for three-dimentional projection. This greatly eases the

specification on the display screen, since there is no immediate requirement to provide retro-reflection selectively to each of the user's eyes.

Some potentially severe electro-optics problems are avoided by electing to design the scanning system to project two rasters, although this requires two separate galvanometers on the helmet and separate relay optics up to the frame scanners. The alternative approach is generation of a single raster which must fill the IFOV field and be capable of the resolution required for the AOI. This implies a need to generate resolved pixels at rates in excess of 200 MHz. Components at or beyond current state-of-the-art are reqired (a) to provide pixel speed-up for the CIG signal assigned to the AOI channel, (b) to intensity modulate, and (c) to provide line scan. The fiber optic link for the single raster must have approximately 4000 fibers in the row used compared with 1000 per bundle given the present NTEC approach. If two separate rasters are projected, the signal bandwidths implied are easily handled by conventional electronics, modulators and line scanners.

Thus, within the CIG and display components, development problems are reduced mainly at the expense of bulk on the user's helmet. The current estimate of weight for the helmet, based on weight of existing galvanometers, some detailed optical design and outline design of mounting structure, is 2.5 lbs.

Some CIG development will be required. A contract has been awarded to General Electric, Daytona to recommend modifications to the VTRS-CIG to allow it to interface to the display system. These modifications include: Capability for two channels to select and process different levels of detail simultaneously from the same active environment; capability to interface simultaneously to the host computer, the head tracking system and the eye tracking system; capabilty to provide distortion correction in both channels; capability to synchronize output video with a roughtly synchronized line scanner; capability to blank and blend inset AOI with surrounding IFOV; and capability to provide offset signals to the line scan offset and frame scan galvanometers to follow eye movements and compensate for errors due to rapid head attitude rates. As of this writing, the CIG modifications are considered low risk developments.

The most severe residual development problems are considered likely to be found in the areas of head tracking and eye tracking. Fast, precise head tracking is vital to any helmet-mounted system for stability of the projected image. While eye-tracking need not be precise, a method must be identified which has high reliability,

which can be set up rapidly, and which is acceptable to pilots - probably ruling out most of the current clinical techniques.

The present status of the NTEC investigations of head- and eye-tracking are described below.

1.8 HEAD TRACKING

The head tracking system is required to measure yaw, pitch and roll of the observer's head relative to the simulated cockpit structure. In order to determine performance requirements on the head tracking system a helmet mounted sight (Polhemus Spasyn Helmet Mounted Sight Model IIIA) has been procured. This system was interfaced to the VTRS CIG system which, in turn, supplied video to a miniature projection CRT mounted on a helmet.

This equipment was then utilized to perform a subjective evaluation experiment. The experiment consisted of having the CIG fly along a canned flight path over an environment consisting of an airfield and surrounding terrain. The observer's head direction determined the viewing direction used by the CIG to compute the scene.

The observed defects in image stability were:

a. A noticeable angular displacement of objects in the scene while the observer's head is rotating.

b. An occasional jitter of the displayed imagery even when the head tracking system sensor was fixed relative to the transmitter and cockpit.

The angular displacement with observer's head rotation was found to be directly related to the known throughput delay of the head-tracking and CIG system. The total delay is 0.1 sec, so that a 30°/sec head rotation rate produces a 3° image displacement. This effect was judged to be objectionable and an effort is underway to correct the defect by dynamically displacing the raster. The amount of angular displacement is made equal to the difference between current (or most recent) measured head attitude and the head attitude utilized to compute the current scene. This approach causes the instantaneous field of view to be reduced by the amount of the motion compensating displacement during head motion. As of this writing, the hardware has been fabricated using a microprocessor and the software program completed. However, the evaluation was not yet underway. This technique should eliminate the effect of CIG throughput delay at the expense of reduced instantaneous field of view during head motions. The effect of head tracking system throughput

delay cannot be eliminated but may be reduced utilizing linear extrapolation. The capability to perform linear extrapolation is included in the microprocessor and will be evaluated concurrently with the CIG throughput delay compensation scheme outlined above.

The magnitude of the display jitter, using the current head-tracking device, was approximately 15 milliradians. Measurement of signals indicated that a large part of this system noise originated in the internal components of the head tracking system. As of this writing, the manufacturer has agreed to evaluate the system.

An in-house analysis of alternative electro-optic techniques for head attitude sensing is being pursued. For use in a simulator, it should be feasible to improve on existing head-trackers which were designed for use in a real cockpit environment, since the simulator environment permits much greater flexibility in design.

1.9 EYE ATTITUDE MEASUREMENT SYSTEM

The eye attitude measurement system provides the CIG with the viewing direction needed to place the high detail area of interest in that part of the projected field corresponding to the observer's central vision. The eye direction information is not used to stabilize the resultant display but direction information is not used to stabilize the resultant display but merely to select the area within which high detail and resolution appear, so that the measuring device may have relatively poor precision, accuracy and response. Some of the design goals for the eye tracking system are: (1) to be visually unobtrusive, (b) a precision of $\pm 2^{o}$, (c) an accuracy (relative to head pointing direction) of $\pm 2^{o}$ and, (d) a response time of less than 16 milliseconds. Experiments utilizing a one-axis (azimuth only) limbus tracker indicate that these requirements will suffice provided that the width of the AOI is 25^{o} or more, and the response time (sum of eye tracker and CIG response times) is less than 100 milliseconds. (The experiments were carried out using photographic imagery, with variable resolution but not variable detail, so that applicability to CIG imagery is somewhat questionable.)

If the total throughput delay is too large, a technique utilizing saccadic prediction may be required. Such a system is currently being developed under a contract with Carnegie-Mellon University (Dr. Terry Bahill - Principal Investigator). Dr. Bahill is also investigating the use of electro-oculography (EOG).

Reference 3 provides an excellent survey of eye attitude measurement techniques and limitations. Ideally, the selected method for eye tracking will require no attachments to the subject's head. Although remote oculometers exist, they are not capable of measuring eye attitude for a large range of head rotations, and the use of multiple remote oculometers to cover all likely head attitudes does not seem practical. The least obtrusive head-mounted technique for eye tracking is EOG. This method requires electrodes to be taped to the subject's face, but the elecrodes are not found seriously objectionable and they do not have significant weight or obstruct the subject's vision in any way.

For these resons, EOG is considered a promising method for use in eye-coupled flight simulation displays. EOG techniques are notorious for drifting but drift can be corrected in theory by automatic recalibration utilzing a single remote oculometer which will provide a reading whenever the observer is looking within 10° of it. Thus a combination of two unobtrusive techniques may prove feasible.

The eye-attitude measuring system remains a high risk area. However, a system which has no eye tracking, in which the AOI remains in the center of the head-tracked IFOV, is considered a viable alternative. In this case, the area of the AOI would be increased, with some loss of resolution, to encompass most normal eye rotations with respect to the head.

1.10 SUMMARY AND CONCLUSIONS

A visual simulation system has been described which takes advantage of human visual system limitations to provide a display which will be perceived as having both high resolution and very wide angle, utilizing only two display/image generator channels. The system design appears feasible utilizing available technology with the exception of two high risk areas namely: head attitude and eye attitude measurement systems.

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APPENDIX C
SFTS TRAINING SUMMARY

1.0 TRAINING REQUIREMENTS

The Aviation Center (USAAVNC) has developed a matrix of tasks required of Army helicopter aircrews and has identified the helicopter in which each such task must be performed. The tasks are those identified in the Aircrew Training Manual, supplemented by tasks required to operate certain equipment on board specific Army helicopters. Figure C-1 consists of extracts from that matrix of tasks relevant to each of the helicopters of interest to the present study.

2.0 OVERVIEW OF PRESENT USAAVNC TRAINING

Qualification training involving use of flight simulators is currently being conducted at the Aviation Center for the AH-1, CH-47, and UH-60.[1] In addition, training for CH-47 instructor pilots who will conduct training at units where CH-47 simulators are located is also conducted at the Aviaiton Center. These training courses are described below.

2.1 CH-47 Aircraft Qualification Course (AQC)

Training for this course is conducted in both CH-47 aircraft and the CH-47 Flight Simulator (FS). The basic AQC consists of 21 aircraft hours and 18.2 hours in the flight simulator flown during 32 training days. For individuals assigned to units with CH-47D aircraft, an additional 10 hours in the CH-47D is provided during eight additional training days. Proficiency advancement is utilized throughout this course.

The basic AQC is presented in two stages and, when required, is a third stage for the CH-47D.

Stage I consists of 11 aircraft hours and 14.3 FS hours flown during 21 training days. An academic program for systems starts one week prior to flight training and parallels flight training providing enabling knowledge prior to flight. The first 9.1 hours of Stage I is flown entirely in the FS. It concentrates on basic contact flight maneuvers and emergency procedures. The second part of Stage I is 4.1 hours in the aircraft, reinforcing the maneuvers and procedures presented in the FS. The next

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[1] The UH1FS, which is used in the Aviation Center training, is not addressed in this summary.

FLYING TASK LIST FOR SELECTED ARMY HELICOPTERS

ATM #	TASK TITLE	AH-1	CH-47	UH-60	AH-64
1001	Plan a VFR flight	X	X	X	X
1002	Plan an IFR flight	X	X	X	X
1003	Prepare DD Form 365F (Weight and Balance)	X	X	X	X
1004	Use Performance Charts	X	X	X	X
1005	Prepare Performance Planning Card (PPC)	X	X	X	X
1501	Perform preflight inspection	X	X	X	X
1502	Perform before takeoff checks	X	X	X	X
1506	Perform ground taxi		X	X	X
2001	Perform takeoff to a hover	X	X	X	X
2002	Perform hover power check	X	X	X	X
2003	Perform hovering turns	X	X	X	X
2004	Perform hovering flight	X	X	X	X
2005	Perform landing from a hover	X	X	X	X
2501	Perform normal takeoff	X	X	X	X
2502	Perform simulated maximum performance takeoff	X	X	X	X
2503	Perform rolling takeoff		X	X	X
3001	Perform straight-and-level flight	X	X	X	X
3002	Perform (normal) climbs and descents	X	X	X	X
3003	Perform turns	X	X	X	X
3004	Perform deceleration/acceleration	X	X	X	X
3005	Perform traffic pattern flight	X	X	X	X
3006	Perform fuel management procedures	X	X	X	X
3007	Perform high-speed flight	X			X
3010	Perform navigation by pilotage and dead reckoning	X	X	X	X
3011	Perform doppler navigation	X	X	X	X
3025	Perform flight with AFCS servo off		X	X	X
3102	Perform positive and negative "G" flight				X
3501	Perform before landing checks	X	X	X	X
3502	Perform normal approach	X	X	X	X

FIGURE C-1

FLYING TASK LIST FOR SELECTED ARMY HELICOPTERS (cont'd)

ATM #	TASK TITLE	AH-1	CH-47	UH-60	AH-64
3504	Perform shallow approach	X	X	X	X
3505	Perform steep approach	X	X	X	X
3506	Perform go-around	X	X	X	X
3507	Perform roll-on landing		X	X	X
3510	Perform confined area operation	X	X	X	X
3511	Perform slope operation	X	X	X	X
3512	Perform pinnacle/ridgeline operation	X	X	X	X
4001	Perform hovering autorotation	X			
4002	Perform standard autorotation	X	X	X	X
4003	Perform standard autorotation with 180 degree turn	X		X	
4004	Perform low-level autorotation	X		X	
4005	Perform simulated hydraulic system malfunction	X	X	X	X
4006	Perform simulated antitorque malfunction	X		X	X
4007	Perform manual throttle operation (emergency governor)	X			
4008	Perform simulated engine failure at altitude	X	X	X	X
4009	Perform simulated engine failure at hover	X	X	X	X
4010	Perform emergency procedures for actual or simulated NVG failure	X	X	X	
4018	Perform low-level, high speed autorotation	X			X
4019	Perform running landing	X			
4020	Perform simulated engine failure, high speed at altitude	X			X
4021	Perform flight with SCAS/SAS/AFCS off	X	X	X	X
4022	Perform Electronic Control Unit (ECU) lockout operation			X	X
4023	Perform single engine failure with roll-on landing		X	X	X
4024	Perform emergency procedures for stabilator malfunction			X	X
4026	Perform emergency procedures for emergency landing	X	X	X	X
4027	Perform emergency procedures for flight control system malfunction	X	X	X	X
4028	Perform emergency procedures for engine system malfunction	X	X	X	X
4029	Perform emergency procedures for fires	X	X	X	X
4030	Perform emergency procedures for fuel system malfunctions	X	X	X	X

FIGURE C-1 (cont'd)

FLYING TASK LIST FOR SELECTED ARMY HELICOPTERS (cont'd)

ATM #	TASK TITLE	AH-1	CH-47	UH-60	AH-64
4031	Perform emergency procedures for electrical system malfunction	X	X	X	X
4032	Perform emergency procedures for rotor, transmission, and drive train malfunctions	X	X	X	X
4035	Perform antitorque failure at a hover				X
4134	Perform emergency descent				X
4501	Perform instrument takeoff	X	X	X	X
4503	Perform radio navigation	X	X	X	X
4504	Perform holding procedure	X	X	X	X
4505	Perform unusual attitude recovery	X	X	X	X
4506	Perform radio communication procedures	X	X	X	X
4508	Perform NAVAID approach	X	X	X	X
4509	Perform ground controlled approach	X	X	X	X
4512	Perform tactical instrument takeoff	X	X	X	X
4513	Perform tactical instrument approach	X	X	X	X
4517	Perform Command Instrument System (CIS) operations		X		
5001	Perform terrain flight mission planning	X	X	X	X
5002	Perform terrain flight navigation	X	X	X	X
5003	Perform low-level flight	X	X	X	X
5004	Perform contour flight	X	X	X	X
5005	Perform nap-of-the-earth (NOE) flight	X	X	X	X
5006	Perform masking/unmasking	X	X	X	X
5007	Perform NOE deceleration	X	X	X	X
5008	Perform out-of-ground effect (OGE) hover check	X	X	X	X
5009	Perform terrain flight takeoff	X	X	X	X
5010	Perform terrain flight approach	X	X	X	X
5011	Perform FM radio homing	X	X	X	X
5012	Perform visual glideslope approach and landing	X	X	X	X
5014	Perform tactical instrument flight planning	X	X	X	X
5018	Perform evasive maneuvers	X	X	X	X

FIGURE C-1 (cont'd)

FLYING TASK LIST FOR SELECTED ARMY HELICOPTERS (cont'd)

ATM #	TASK TITLE	AH-1	CH-47	UH-60	AH-64
5019	Operate radar warning receiver AN/APR 39	X	X	X	X
5020	Perform ski landing	X			
5021	Perform preflight inspection of ski installation	X			
5022	Perform hover/taxi over snow	X	X	X	X
5024	Perform techniques of movement	X			X
5025	Identify US/allied and threat weapons and aircraft	X	X	X	X
5027	Perform laser beacon operations				X
5029	Perform water operations		X		
5030	Perform circling approach from terrain flight	X	X	X	X
5033	Negotiate wire obstacles	X	X	X	X
5035	Perform recognition of hazards to terrain flight	X	X	X	X
5036	Perform as a crew member (cockpit teamwork)	X	X	X	X
5100	Operate communications equipment	X	X	X	X
5106	Operate chaff dispenser	X	X	X	X
6001	Perform multi-aircraft operations (formation flight)		X	X	
6011	Perform external load operations		X	X	
6016	Perform target handoff to attack helicopters	X			X
6044	Supervise installation and loading of weapons	X			X
6045	Preflight aircraft weapon systems	X			X
6046	Operate Heads-Up Display (HUD)	X			
6047	Operate Rocket Management System (RMS)	X			X
6049	Perform weapons cockpit procedures	X			
6050	Operate M28/M197 turret system	X			
6051	Operate M28/M197 turret system using helmet sight system	X			
6054	Operate reflect sight M73/M60	X			
6055	Operate 2.75 inch FFAR rocket launcher	X			X
6056	Operate M35 (20mm) weapon system	X			
6057	Operate Telescopic Sighting Unit (TSU)	X			
6058	Operate TOW missile system	X			

FIGURE C-1 (cont'd)

FLYING TASK LIST FOR SELECTED ARMY HELICOPTERS (cont'd)

ATM #	TASK TITLE	AH-1	CH-47	UH-60	AH-64
6060	Describe emergency procedures for aircraft armament system malfunctions	X			X
6061	Safe and clear weapon systems	X			X
6063	Perform terrain flight firing techniques	X			X
6065	Perform entry to and egress from firing positions	X			X
6066	Acquire and identify targets	X	X	X	X
6067	Engage targets by direct/indirect fire	X	X	X	X
6501	Perform after landing tasks	X	X	X	X
----	Operate IR jamming equipment	X	X	X	X
----	Operate IHADDS/HDU				X
----	Operate fire control computer (FCC)				X
----	Operate Hellfire missile system				X
----	Operate XM-230E1 (30mm) weapons system				X
----	Perform PNVS operational checks				X
----	Operate A/C using PNVS				X
----	Perform TADS turn-on procedures				X
----	Perform TADS				X

FIGURE C-1 (cont'd)

5.2 hours is in the FS and includes advanced contact maneuvers and emergency procedures. This is followed by another 5.8 hours of aircraft time including night flight and a flight evaluation.

Stage II consists of 10 aircraft hours and 3.9 FS hours. The aircraft training includes cargo helicopter tactics, additional night flight, and another evaluation. The FS training is devoted to tactical instrument flight, emergency procedures, and high gross weight and external load operations.

Stage III consists of 10 hours of aircraft time flown in the CH-47D during eight training days. This training time includes 7.5 hours of day visual contact flight and emergency procedurs, 1.0 hours of night flight, 1.0 hours of instrument flight, and 1.5 hour flight evaluation.

2.2 CH-47 Instructor Pilot Course (IPC)

The basic IPC (Stages I-IV) consists of 47.5 aircraft hours flown during 35 training days. The basic IPC does not include any flight simulator training periods. The CH-47D qualification consists of an additonal 10 aircraft hours flown during 8 training days. For those students being assigned to installations with a CH 47FS (Fort Rucker, Fort Campbell, Fort Hood, Germany), the flight simulator MOI consists of 31 hours flown during nine training days.

The IPC consists of six stages listed below:

(a)	Stage I (Flight Proficiency)	5.2 aircraft hours
(b)	Stage II (Contact MOI)	17.7 aircraft hours
(c)	Stage III (Tactical MOI)	14.1 aircraft hours
(d)	Stage IV (Night MOI)	10.5 aircraft hours
(e)	Stage V (CH-47D Qualification/MOI)	10.0 aircraft hours
(f)	Stage VI (Flight Simulator MOI)	31.0 FS hours

The FS MOI consists of learning the organization and operation of the various flight simulator instructional training features and practice utilization of these features. The final three hour period is designed to evaluate the instructor pilot students' ability to brief and demonstrate the total system capability.

2.3 UH-60 Aircraft Qualification Course (AQC)

This course consists of flight and academic training in the safe operation of the UH-60 helicopter in transition and tactical maneuvers and load operations, and

provides students with a working knowledge of aircraft maintenance and systems, navigation and command instrument systems, and the Doppler Navigation Set.

The course consists of 17.2 dual flight training hours, (nine aircraft hours and 8.2 flight simulator (FS) hours). The flight time is flown during 12 training days. An academic program parallels the flight program and is used to present requisite material in advance of related flight hours.

The course includes 11.1 hours of visual contact flight. 4.5 hours of this time is in the FS, 1.0 hours night flight in the aircraft, 3.7 hours instrument flight in the FS, and 1.4 hour flight evaluation.

The flight simulator is being used to provide cockpit procedural training, visual contact training, and instrument training.

Since the Doppler Navigation System is the UH-60's primary means for tactical navigation, use of this system is encouraged throughout all flight training periods. The UH-60 FS is used to conduct flight evaluations of the Command Instrument System.

2.4 AH-1 Aircraft Qualification Course (AQC)

This course consists of flight and academic training in the safe operation of the AH-1S helicopter in transition maneuvers, combat skills/gunnery training and to provide students with a working knowledge of aircraft weapons systems.

The course consists of 35 aircraft flight hours and three flight simulator hours flown during 29 flight periods. An academic program parallels the flight program and is used to present the requisite material in advance of related flight hours.

The course consists of two phases, the transition phase and the combat skills/gunnery phases. The transition phase includes 14.7 aircraft hours of visual contact flight and 2.6 aircraft hours of night flight. The combat skills/gunnery phase includes 12.5 aircraft hours of visual contact flight, 5.2 aircraft hours of night flight and three hours of simulator flight.

The design basis aircraft for the AH 1FS were the AH-1G and AH-1Q. The rear cockpit design was based on the AH-1G and the front copilot gunner cockpit the AH-1Q. Both these AH-1 models are obsolete. As a consequence, very little aircraft-specific training can be accomplished effectively in the flight simulator. The three hours of flight simulator time in this course are utilized to provide training with the telescopic sighting unit, TOW missile system acquisition and tracking, gunners helmet

sight or telescopic sight unit, operation of the M97 turret system and operation of some emergency systems. This prototype AH IFS is scheduled to be modified in the near future using the AH-1S as the design basis aircraft. With this modification, the simulator will be able to provide significantly more training capability to the aircraft qualification course.

3.0 PROPOSED AH-64A QUALIFICATION PROGRAM

The AH-64 qualification program will consist of five phases of training. Each phase will probably become annexes to the AH-64 Qualification Course POI. The phases include I, PNVS; II, Transition; III, Pilot Terrain/Weaponization; IV, Front Seat Gunnery; and V, Combat Skills.

Hughes Helicopters Incorporated (HHI) will develop Phase I through IV. The Army will develop Phase V. HHI will provide initial training (Phase I-IV) in Yuma, Arizona, to the first group of individuals to be designated instructors in the AH-64. These individuals will then teach themselves the combat skills training phase. They will then be designated AH-64 IP's.

The qualification POI will then be initiated at Fort Rucker, Alabama with HHI trained IP's. An additional Methods of Instruction (MOI) phase will be added to the POI for selected students who are current AH-1 IP's, during the first five or six courses conducted at USAAVNC.

The qualification course length will be 14 weeks in duration and include 65 aircraft flight hours (24 hours AH-1 surrogate with PNVS and 41 hours AH-64), 20 hours in the Cockpit Weapons Procedures Trainer (CWEPT), six hours in the TADS Selected Task Trainer (TSTT), and 15 hours in the AH-64 Combat Mission Simulator (CMS). This device training is summarized in Figure C-2. An academic program will parallel the flight program and present requisite material in advance of the related flight hours.

Phase I (PNVS) will consist of five days of academics followed by 17 days and 24 flight hours in the AH-1 (surrogate).

Phase II (Transition) will consist of 13 hours of flight time in the AH-64 for basic transition flight tasks. The flight periods will be preceded by three days of

SUMMARY OF AH-64 TRAINING MEDIA/HOURS	
DEVICE	**HOURS**
AH-1	24
AH-64	41
CWEPT	20
TSTT	6
CMS	15

FIGURE C-2

CWEPT training. CWEPT time will consist of six hours of cockpit familiarization, pre-start, start, runup, and some systems training. During the first five days of transition flight training, students will receive four more hours of CWEPT time devoted to cockpit procedures and aircraft systems. All CWEPT time in Phase II will be rear seat time. However, a second student will occupy the front seat of the CWEPT during this training, and monitor rear seat training from there.

Phase II (Pilot Terrain/Weaponization) is an eight day block of training which includes 10 hours of AH-64 aircraft time in the rear seat. It will include terrain flight with PNVS, firing 2.75 inch rockets, and firing the 30mm chain gun. Additionally, students will receive 10 hours of front seat training in the CWEPT for front seat weaponization training, and six hours in the TSTT.

Phase IV (Front Seat Gunnery) is a 12 day block of training which includes 15 hours of front seat gunnery training in the AH-64 aircraft. The students will fire the 2.75 inch rockets and the 30mm chain gun, and will practice HELLFIRE procedures and tracking. The AH-64 has a railmounted HELLFIRE training missile which will be utilized during this phase of training.

Phase V (Combat Skills) is a 15 day block of training which includes 18 flight hours. Three of these hours are scheduled in the AH-64 and the other 15 in the CMS. The USAAVNC is currently developing five combat scenarios for CMS training. There will be ten 1.5 hour training periods flown in the integrated mode of CMS operation. Each pair of students will fly five rear seat periods and five front seat periods, thus repeating each scenario twice; once from the rear seat, and again from

the front seat. The plan is to alternate seats and scenarios daily. Of the 10 periods, eight will be training periods (six night missions and two day mission). The remaining two periods will be utilized for evaluations. One period will be a rear seat night evaluation, and the other will be a front seat night evaluation.

In the event the CMS is not ready for training when the qualification course is implemented at USAANVC, two alternative options are currently being entertained. Option one is to include 18 hours in the AH-64 to meet the Combat Skills phase training objectives. The second option is to provide 11 hours in the aircraft and an additional 7 hours of integrated crew training in the CWEPT, and 14 hours in the TSTT.

Plans for AH-64 instructor training are incomplete. According to personnel at the Aviation Center involved in developing the AH-64 POI's, the decision related to who will conduct simulator training has not been made. The simulator instructor may not be the same instructor who conducts the AH-64 aircraft training.

4.0 OVERVIEW OF CH-47 UNIT TRAINING

In addition to the prototype CH 47FS located at Fort Rucker, Alabama, which is used for initial qualification and instructor pilot training, the Army has taken delivery of three production CH 47FS for use with field units. Aircrew training programs as prescribed in Training Circular No. 1-139 (ATM Cargo Helicopters) were initiated at Fort Campbell, Kentucky, in May 1982; at Fort Hood, Texas, in August 1982; and in Mannheim, Germany, in November 1982.

The purpose of TC 1-139 is to establish initial qualification and continuation training requirements and to provide Army commanders recommended training programs for refresher, mission, and continuation training. Additionally, it serves to provide standardization of aviator training programs and standardization of flight evaluations.

Initial qualification training defines the minimum academic and flight training needed for the qualification training of aviators, unit trainers, instructor pilots, and standardization instructor pilots in cargo helicopters. The refresher training program is designed for initial aviators to regain proficiency in all flight activity category 2 (FAC 2) tasks in an aircraft in which they have been previously qualified. Refresher training programs are initiated after individuals have been administered proficiency flight evaluations. Then a program is structured focusing upon individual deficiencies.

Mission training programs are designed to expand the aviators ability to perform the flight activity category 1 (FAC 1) tasks and additional tasks selected by the

commander to support unit missions. This phase of training is entered after completion of initial qualification training and refresher training. This training program emphasizes tasks that are unique to a unit's operational mission.

Continuation training is conducted to maintain aviator currency and proficiency in the respective aircrew positions. This training is designed to keep each aviator proficient in all tasks. Each category of aviator is required to perform specific iterations of selected tasks and fly a specific number of flight hours semiannually. Aviators assigned as CH-47 crewmen may fly (if available) the CH 47FS a minimum of 20 hours and may reduce their semiannual flight requirement up to 19 hours.

With only four CH 47FSs available, the Army has elected to centralize various aviator training programs. Thus, the CH 47FS not only provides aviator training to individuals assigned to a specific post with a CH 47FS (Fort Rucker, Fort Campbell, Fort Hood, and Mannheim, Germany), but also to aviators sent from other posts and installations to these four installations to meet training requirements. From a training standpoint it is more economical to send aviators from Fort Carson to Fort Hood or Fort Rucker than to utilize operational aircraft to meet training requirements.

4.1 Germany

The CH 47FS in Mannheim, Germany, primarily provides training to aviators assigned to three cargo helicopter companies. One company is co-located at the simulator site; the other two companies are at two remote sites. Aviators from the remote sites travel to the simulator site for required training. These CH-47 pilots are required to fly 26 hours per year in the CH 47FS.

The majority of the simulator training is continuation training. These training programs were developed by the individual helicopter companies with assistance from facility support instructor pilots. Each of the helicopter company instructor pilots (IP), instrument flight examiners (IFE) and standardization instructor pilots (SIP) have been trained as instructors in the CH 47FS. They (the IP, IFE, and SIP) conduct all of the units' training in the simulator. In that way the training is responsive to the commanders' mission training requirements. There are two instructor pilots assigned to the simulator facility available to assist units with their training requirements as necessary.

The CH 47FS training program developers utilized the ATM task requirements as the basis for program development. From this a series of mission-oriented flight scenarios were developed to present the required training. These scenarios

include ATM and unit-unique training requirements. The training includes visual contact flight, tactical instrument flight, standard instrument flight, tactical mission training, and emergency procedure training.

4.2 Fort Campbell

The CH 47FS at Fort Campbell, Kentucky, is used to provide training to aviators assigned to the three cargo helicopter companies assigned to Fort Campbell. Additionally, the simulator is used to provide training to CH-47 qualified aviators from the Panama Canal Zone, the Washington State National Guard, Pennsylvania National Guard, and military aviators assigned to the Boeing helicopter facility.

Aviators at Fort Campbell are required to fly the simulator 20 hours each semiannual period.

The majority of the simulator training is continuation training. The training programs are developed and conducted by individual unit IPs, IFEs, and SIPs. The training is designed to meet ATM requirements and unique unit mission requirements. The training includes visual contact flight, tactical instrument flight, standard instrument flight, tactical mission training, and emergency procedures training. One unique training application the CH 47FS is being used for is night vision goggle (NVG) training. A modification to the simulator lighting and light control system permits effective NVG training to be accomplished in the simulator. As simulator training time permits, AH-1 and UH-60 aviators also receive NVG training in the simulator.

4.3 Fort Hood

The CH 47FS at Fort Hood, Texas, is used to provide training to one company assigned to Fort Hood. Additionally, this simulator provides training time to a company from Fort Sil, Oklahoma, a company from Fort Carson, Colorado, the company at Fort Lewis, Washington, a company in Alaska, the California National Guard, the Texas National Guard, and the Kansas Army Reserve.

Aviators utilizing the CH 47FS at Fort Hood fly approximately 20-15 hours each annually in the simulator. The training programs were developed from the ATM. The programs are designed for refresher training, instrument requalification and aircraft re-current training. Each aviator has a program that is structured to meet his particular training requirements. These requirements are determined via administration of a proficiency checkride to identify proficiency deficiencies. Training includes visual contact flight, tactical instrument flight, standard instrument flight, tactical

mission flight, and emergency procedures training. Approximately 60 percent of the training is in a visual environment and 40 percent in the instrument enviornment.

A significant difference in the utilization of the simulator at Fort Hood as opposed to Fort Rucker, Fort Campbell, and Germany is the employment of device operators as instructors. These individuals are permanently assigned to the simulator facility and operate the instructor station during all training missions. When unit flight instructors or flight examiners accompany aviators from their units, they occupy the observer seat to manage the training process.

Several major changes were incorporated in the CH 47FS field production units. These changes include changing the scale of the terrain model board from 1500:1 to 1000:1. Since the terrain model is used in the visual generation system, the quality of the cockpit display is improved. Pilot and copilot side window displays have also been added, along with a second terrain model board and visual display generation system. These changes combined with some aircraft system changes significantly increase the training capability of the CH 47FS production unit over the prototype at Fort Rucker.

5.0 U.S. ARMY FLIGHT SIMULATORS

The U.S. Army has a family of flight simulators collectively known as the Synthetic Flight Training System ([illegible]). The SFTS currently includes simulators, either under contract or at military installaitons, for the UH-1, CH-47, AH-1, UH-60, and AH-64. Descriptions of the CH-47, AH-1, UH-60, and AH-64 are included in the following section. Figure Table C-3 presents the current and proposed locations for the SFTS. This information was provided by the USAAVNC and the PM TRADE.

5.1 CH-47C CHINOOK Flight Simulator (CH 47FS)

The CH 47FS is designed to provide training in normal visual and instrument maneuvers, operating procedures, and emergency procedures. The prototype and production units include a trainee station, with positions for both pilot and copilot trainees. A training task analysis and fidelity analysis determined that this station should be a replica of the actual aircraft. To the rear of the trainee station and within the same enclosure is an instructor station equipped with the necessary controls, indicators, and displays to enable control and management of the training process. The instructor station design and arrangement is based upon a human engineering analysis and instructor training requirements analysis to facilitate an

U.S. ARMY SIMULATOR LOCATIONS

LOCATION \ SIMULATOR	UH1 FS	CH-47 FS	AH1 FWS	UH-60 FS	AH-64 CMS
Ft. Rucker, Alabama	8	1	1 ***	1	*
Ft. Campbell, Kentucky	1	1	** RFT Jan 85	*** (2)	***
Ft. Hood, Texas	1	1	** RFT May 84	***	***
Ft. Lewis, Washington	1	** RFT May 86	** RFT Jul 85	***	
Mannheim, France		1			
Hanau, France	1		** RFT Aug 84	***	***
Illesheim, France		** RFT A[illegible]. 85	***	***	
Korea	1	** RFT Sep 86		*** (2)	
Ft. Bragg, North Carolina	1			***	
Hawaii	1			***	
Ft. Ord, California	1			***	
Ft. Riley, Kansas	1			***	
Ft. Carson, Colorado				***	
Ft. Stewart, Georgia	1			***	
Ft. Polk, Louisiana				***	
Indiantown Gap, Pennsylvania	1		***		
Phoenix, Arizona			**		
Ft. Knox, Kentucky	1				
Ft. Sill, Oklahoma	1				
Ft. Belvoir, Virginia	1				

* Prototype under contract

** Production under contract

*** BOIP proposed contract award pending

FIGURE C-3

effective instructor/trainee interface. Included in the instructor station is an observer station which permits monitoring of both trainee and instructor activities.

The instructor/trainee station is mounted upon a six-degree-of-freedom motion system. This system provides pitch, roll, yaw, vertical, lateral, and longitudinal motion cues. A high resolution camera model visual system with a 1500: 1 three dimensional 56 feet long by 24 feet high terrain model is provided with the prototype unit. To improve the quality of the visual display system, the scale on the production units was changed to 1000:1. The production unit also includes a dual terrain model which not only provides front window displays for the pilot and copilot, but side window visual display scenes for an increased training capability. The video camera is mounted on a gantry that is synchronized to respond to cockpit control inputs and provide visual displays through the pilot's and copilot's front windows. Each trainee has additional displays at the chin window location consisting of computer generated symbology which provide relative altitude and motion cueing when the simulated aircraft is maneuvering close to the ground at designated landing sites.

Realtime simulation of the CH-47C and management of all related advanced training, navigation/communication, aircraft subsystems, and visual display system programs is provided by a digital computer complex. A DEC PDP 11/45 computer system provides the primary computation system.

5.2 CH-47D CHINOOK Flight Simulator (CH 47DFS)

The CH 47DFS is designed to provide cockpit preflight and starting procedures, training in aircraft control, visual takeoff and landing procedures (including landing in confined areas), and pinnacle and load operations (excluding slope operations). In addition, the CH 47DFS performance evelope will extend from nap-of-the-earth (NOE) capability to the service ceiling of the aircraft. The simulator will simulate Army serial #81-23385 CH 47D aircraft. The hardware and software baseline for the CH 47DFS is the CH 47CFS production unit. The instructor station, trainee station, observer station, and motion system are essentially identical to the CH-47CFS.

Major aircraft modifications to the CH 47CFS production model for this application include simulation of the T55-L712 turboshaft engine, fiberglass rotor blades, cargo hooks, an advanced flight control system, navigation, and communciation systems, aircraft systems, survivability avionics equipment, and a modified cockpit configuration. Simulator changes include a new technology digital voice system, a

record/playback instructional voice system, and substitution of a computer generated image (CGI) generator visual system with pilot and copilot side and front windows.

5.3 AH-I (COBRA) Flight and Weapons Simulator (AHIFWS)

The AH IFWS is designed to provide training in normal operating procedures, emergency procedures, and gunnery techniques to include delivery of the TOW missile. The trainer consists of two trainee cockpits representing the pilot and copilot stations, respectively. Each trainee station is an authentic replica of the actual aircraft from the aft station of the pilot's seat forward. The design of the trainee stations was determined as a result of training task analysis and fidelity requirements analysis. To the rear of each trainee station and within the same enclosure is an instructor station equipped with the necessary controls, indicators, and displays to enable control and management of the training process. The instructor station design and arrangement is based upon a human engineering analysis and instructor training requirements analysis to facilitate an effective instructor/trainee interface. Included in each instructor station is a location for an observer.

The instructor/trainee station is mounted upon a six-degree-of-freedom motion system. These systems provide pitch, roll, yaw, vertical, lateral, and longitudinal motion cues.

The trainer includes a visual system that provides day and night visual cues to the trainees as well as weapons' effects. This high resolution visual system employs a closed circuit laser camera/television system with three-dimensional terrain models. Two identical 64 feet long by 24 feet high models represent a part of the Fort Rucker training area approximately 11 X 4 nautical miles in area. A laser probe, synchronized with cockpit maneuvers, generates the visual presentation which is seen by the trainee and insructor through the front window. The pilot station also includes a side window to enlarge the field of view available to the pilot when required for certain maneuvers, such as autorotations. By providing two identical model boards, the Army has the option of flying separate training missions for the pilot and the gunner simultaneously or, they can be electronically coupled and provide a team training capability.

Realtime simulation of the AH-I and management of all related advanced training, navigation/communication, aircraft systems and subsystems, and visual display programs is provided by a digital computer complex. A DEC PDP 11/55 provides the primary computation system.

5.4 UH-60 BLACKHAWK Flight Simulator (UH 60FS)

The UH 60FS is designed to provide training in normal visual and instrument maneuvers and operating procedures, emergency procedures and continuation training. Continuation training is primarily oriented toward training and maintenance of tactical flight skills. The trainer consists of a trainee station with positions for both pilot and copilot trainees. A training task analysis and fidelity analysis determined that this station should be a replica of the actual aircraft. To the rear of the trainee station and within the same enclosure is an instructor station equipped with the necessary controls, indicators, and displays to enable control and management of the training process. The instructor station design and arrangement is based upon a human engineering analysis and instructor training requirements analysis to facilitate an effective instructor/trainee interface. Included in the instructor station is an observer station which permits monitoring of both trainee and instructor activities.

The instructor/trainee station is mounted upon a six-degree-of-freedom motion system. This system provides pitch, roll, yaw, vertical, lateral, and longitudinal motion cues. The UH 60FS includes a Digital Image Generator (DIG) four window, three channel, full day-night visual system. To simulate a tactical combat environment, the DIG visual system provides ground muzzle flashes, tracer effects, a ground-to-air missile signature, and moveable enemy tanks. The simulator also permits flight at a four foot wheel height above ground level throughout the entire gaming area, training in confined areas, pinnacle operations, sling loads, and formation flight.

Realtime simulatin of the UH-60 and management of all realted advanced training, navigation/communication, aircraft subsystems is provided by a digital computer complex. A Perkin-Elmer 8/32 computer system provides the primary computation system. An additional Perkin-Elmer 8/32 provides the DIG computation system.

5.6 AH-64A (APACHE) Combat Mission Simulator (AH 64CMS)

The prototype AH 64CMS has been designed to provide a training capability for flight and weapons delivery, normal and emergency procedures, and sensor systems operations. The simulator will include two separate trainee cockpits, one for the pilot and another for the copilot. Each trainee station is an authentic replica of the actual aircraft. The design of the trainee stations was determined as a result of training task

analysis and fidelity requirements analysis. To the rear of each trainee station and within the same enclosure is an instructor station equipped with the necessary controls, indicators, and displays to enable control and management of the training process. The instructor station design and arrangement is based upon a human engineering analysis and instructor training requirements analysis to facilitate an effective instructor/trainee interface. Included in each instructor station is an observer station which permits monitoring of both trainee and instructor activities.

The instructor/trainee station is mounted upon a six-degree-of-freedom motion system. These systems provide pitch, roll, yaw, vertical, lateral, and longitudinal motion cues.

The visual system is Digital Image Generator (DIG) which is current state-of-the-art out-the-window scene and sensor imagery and symbology to each of the appropriate crew members video displays. The simulated imagery includes forward looking infrared (FLIR), day television (DTV) and direct view optics (DVO). Pilot displays consist of the integrated helmet and display sight system, helmet display unit (IHADSS HDU) and a panel mounted video display unit (VDU). Gunner displays include the IHADSS HDU, a target acquisition and designation sight heads down display (TADS HDD), and TADS heads out display (HOD).

The pilot and copilot gunner will have the capability to train individually (independent) or via electronic coupling may train as a team performing integrated combat missions.

Realtime simulation of the AH-64 and management of all related advanced training, navigation/communication, aircraft systems, tactical systems, hostile threat activities, and the visual display programs is provided by an extensive digital computer complex. The computer complex consists of Perkin-Elmer 32/52 and 32/50 computers.

APPENDIX D
DETAILED INSTRUCTIONAL FEATURES
COMMONALITY ANALYSIS

Appendix D is an examination of the instructional features found in the various simulators that comprise the SFTS. It defines these features, describes their purpose and intended use, and describes their current degree of commonality across simulators. For the purpose of this discussion, the features designed into the AH-64 CMS currently under development are considered to be a "baseline" configuration. The feature definitions and descriptions of their purpose and intended use contained in the present report have been extracted with very minor change from the specifications for the AH-64 CMS. Figure D depicts the instructional features to be discussed and the SFTS in which each is found.

SIMULATOR INSTRUCTIONAL FEATURES FOUND IN SYNTHETIC FLIGHT TRAINING SYSTEM SIMULATORS				
	FLIGHT SIMULATORS			
INSTRUCTIONAL FEATURE	AH-64 CMS	AH-1 FWS	UH-60 FS	CH-47 FS
Record/Playback	X	X	X	X
Hardcopy	X	X	X	X
Manual Freeze	X	X	X	X
Automatic Freeze	X	X	X	X
Parameter Freeze	X	X	X	X
Demonstration	X	X	X	X
Demo Prep	X	X	X	X
Malfunction Simulator	X	X	X	X
Store/Reset	X			
Remote Display	X			
Auto Malfunction Insertion	X			
AMI Exercise Prep	X			
Automatic Flight	X			
Automatic Flight Prep	X			
Target Engage Exercise	X			
Target Engage Exercise Prep	X			

FIGURE D

1. Record/Playback

a. Definition

Record/Playback (R/P) is a simulator instructional feature that permits the instructor to replay a recent or immediately preceding segment of simulated flight. During a playback, all events which occurred as a consequence of pilot input to the simulator's controls will be reproduced without such inputs having to be repeated. The playback will repeat the cockpit control movements, cockpit instrument values, cockpit displays, motion cues, visual scenes, mechanical and aerodynamic sounds, and voice communications which occurred during the period of recorded time selected for replay.

The R/P feature continuously records the most recent segment of simulated activities. Recording occurs automatically whenever the simulator is being controlled (flown) from the pilot's station. Periods of Freeze, Demonstration, or control of the simulator from the IOS are not recorded except to the extent that may be required to establish initial conditions. The most recent period of training activity, e.g., five minutes (or all previous activity if less than five minutes of pilot-controlled flight have occurred), will be recorded and continuously available. Recorded flight may be accessed for playback in 10 to 15 second intervals up to the full time available, and access time to the beginning of any such interval must be rapid, e.g., within 15 seconds.

b. Purpose and Intended Use

The purpose of the R/P feature is to enable the pilot to examine his own performance and to aid the instructor in critiquing pilot performance. R/P provides a faithful reproduction of pilot performance that can be examined in detail at a pace determined by the instructor, repeatedly if necessary, while that performance is simultaneously being reviewed by the pilot himself. Its use will permit relationships between pilot control inputs and system responses to be examined, and thus it can be employed with pilots having particular difficulty mastering a specific skill. The R/P feature will be used when new maneuvers or tasks are being trained and when instructor critiques are an important instructional activity. Its frequency of use will decrease as the pilots using the simulator become more proficient in the performance of required tasks.

The most frequent use of the R/P feature will follow an error or a less than satisfactory performance by the pilot. Rather than waiting until a post-training period debriefing to critique such performance, the instructor will interrupt the simulated

flight to replay the performance in question. Using the recording as an aid, he will "debrief" the pilot at that time. Normally, the performance of interest will be of short duration, so the time devoted to the playback will be brief. The duration of the recorded performance that is available is intended to permit the instructor a degree of flexibility in employing the R/P feature. He seldom will replay the entire recording, since to do so would tend to be an inefficient use of training time.

The Freeze function serves the same purpose when the R/P feature is in use as it does during any nonplayback mode of operation in that it "freezes" all parameters at the values which exist at the time Freeze is entered. Regardless of the prior activities, the instructor may end Freeze and (1) continue monitoring the playback in real time with synchronized audio; or (2) continue monitoring the playback in real or slow time without audio. Slow time is a condition in which one unit of real or recorded time is stretched to two units of playback time, i.e., activities are slowed down to facilitate monitoring them. While in freeze status, the instructor also may elect to terminate the playback and continue other instructional activities.

c. Commonalities/Differences

1. Control functions:

Select Interval -	Control to select the number of minutes of playback desired.
R/P Activation -	After selection of desired time interval, activation of playback permits the crew to monitor recorded performance.
Audio Off -	Enables and disables audio during monitoring of playback.
Slowtime -	Activation of this control slows playback time to one half real time.
Terminate -	This function permits stopping the replay at any point after activation and short of completion.
Reset -	This function permits termination of replay at any point and resetting to the point of interruption for replay.
Flyout -	This function permits termination of replay at any point and resuming flight from that point.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Select interval	X	X	X	X
R/P Activation	X	X	X	X
Audio Off	X			
Slowtime	X	X	X	X
Terminate	X	X	X	X
Reset	X	X	X	X
Flyout	X	X	X	X

FIGURE D-1

2. Functional differences:

Select Interval - The UH-60 FS permits selection of 1 to 30 minutes in one minute intervals. The AH-64 CMS, CH-47D and AH-1 FWS permit selection of 1 to 5 minutes.

Audio Off - The AH-64 CMS is the only SFTS with this control function.

3. Hardware differences:

R/P Activation - The AH-1 FWS and CH-47 FS are activated from freeze by selecting a discrete control switch of 1 through 5 minutes.

The UH-60 FS is activated from freeze by selecting from 1 to 30 minutes on thumbwheel selectors and depressing a discrete start switch.

The AH-64 CMS is activated from freeze by selecting a CRT page and entering a specific line number for 1 to 5 minutes via the instructor keypad.

Audio Record - The AH-64 CMS employs a digitized voice recording system to record and store audio commentary during training.

The CH-47 FS, AH-1 FWS, and UH-60 FS employ continuous loop tape cartridges to record and store audio commentary during training.

4. Advantages/disadvantages of design:

Selected Interval. There is no significant advantage for having more than 5 minutes of record playback time. The playback feature is utilized to provide timely feedback of less than satisfactory performance for self-analysis and/or instructor critique. The average time for employing this feature is approximately 3 minutes.

R/P Activation. There are no significant advantages or disadvantages to the methods of implementation of hardware to activate and select time interval for record/playback. Use of the CRT page with the instructor's keypad eliminates need for series of discrete switches and thumbwheel selectros, but it ties up the CRT.

Audio Off. The audio off control permits the instructor to provide his own instruction and commentary during periods of playback.

Audio Record. The advantage of a digitzed voice recording system over a tape system is that it permits the repeat of the record/playback function with synchronized voice as many times as required.

2. Hardcopy

a. Definition

Hardcopy is a simulator instructional feature that enables the instructor to reproduce on a paper medium alphanumeric and graphic data displayed on an IOS CRT. The feature provides a copy of those data as they exist at the time the reproduction is initiated by the instructor. Data permitting subsequent identification of the pilot and the instructional activity underway will appear on each copy generated by this feature.

b. Purpose and Intended Use

The purpose of the Hardcopy feature is to provide the instructor a copy of perishable information displayed at the IOS. The copied display may be used by the instructor to compare the performance of a pilot at two points in time during a single instructional period, or over several such periods, to compare the performance of several pilots on similar flight tasks, to aid the instructor in subsequent review of a pilot's performance, and/or to provide objective information for permanent record purposes. The instructor may write notes on the copy generated by use of this feature as an aid to his subsequent use of the data copied. Use of the hardcopy feature will not affect any aspect of the simulation except for the generation of the copy. This feature may be used independently of other instructional activities in progress.

Although the IOS contains multiple data displays, only one can be copied at a time. The instructor usually will be satisfied to copy single displays or to obtain near-simultaneous copies of multiple displays by copying each one sequentially. However, should the instructor desire copies to be made of multiple displays occurring simultaneously, it would be necessary to preserve the displays until each can be copied by entering freeze status. The time required to obtain copies of more than one display or sequential copies of a single display will be limited by the time required to activate the appropriate IOS controls. The copy generation process may require additional time. Once generated, however, the copy will be available at the IOS for immediate use by the instructor.

c. Commonalities/Differences

1. Control functions:

Activation - Controls located at the instructor station permit generation of hardcopies of graphic and alpha-numeric data displayed on the instructor station CRTs.

Multiple Copy - Permits the instructor to obtain copies from multiple CRTs or multiple (sequential) copies from a single CRT.

Select Display - Permits selection of the CRT to be copied.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Activation	X	X	X	X
Multiple Copy	X	X	X	X
Select Display	X	X	X	X

FIGURE D-2

2. Functional differences:

Activation - The CH-47 FS, AH-1 FWS, and UH-60 FS permit storing CRT data for up to 20 display pages while training activities are in progress. To print

hardcopy of displays, the simulator must be infreeze and in an off-line operational mode.

The AH-64CMS has the capability to provide copies of the instructor CRT display data individually or sequentially on-line without affecting training in progress. The copy is immediately available to the instructor.

3. Hardware differences:

Activation - The CH-47 FS, AH-I FWS, and UH-60FS have discrete switches to store (STORE PLOT) up to 20 CRT display pages. They also have an OFF LINE control switch and a PRINT PLOT switch which must be activated to print the stored CRT displays from a freeze condition.

The AH-64 CMS has a single discrete switch (HARDCOPY) which, when activated, immediately copies and prints the CRT display data. The simulator need not be in freeze status.

Select Display - The CH-47 FS and the UH-60 FS both have dual CRTs at the instructor station. Data displayed on the forward CRT may be stored and printed. Each device has discrete control switches to interchange data between forward and aft CRTs.

Other - In the CH-47 FS, AH-I FWS, and the UH-60 FS, when the PRINT PLOT switch is activated the stored data is printed on a hardcopy printer. These printers are outside the instructor station enclosure, and the instructor must leave the instructor station to retrieve the data. Printing time for each page averages 10 seconds.

In the AH-64 CMS, when the HARDCOPY switch is depressed an immediate print of the CRT data is generated at the instructor station. The hardcopy is then available to the instructor for critiquing or reviewing student performance. Printing time for

each page averages 10 seconds; however, the disc storage will accept up to five copies in rapid sequence while printing.

4. Advantages/disadvantages of design:

The disadvantages to the CH-47 FS, AH-1 FWS, and UH-60 FS are (1) the limitation of 20 copies per training period (i.e., 10 per simulator cockpit) and (2) the hardcopies are not available until the training period is completed unless the instructor elects to interrupt training to recover copies.

The advantages of the AH-64 CMS onboard printer are (1) immediate availability of hardcopy at the instructor station, (2) no limitation on number of copies, and (3) no interruption to the training process while requesting and receiving hardcopies.

3. Manual Freeze

a. Definition

Manual Freeze (MF) is a simulator instructional feature that enables the instructor or the pilot to freeze or suspend ongoing simulated activity resulting from input to the aircraft's controls (in the cockpit and at the IOS), from recorded data, or from computer-generated data. During the period of suspension, the simulated conditions existent at the onset of MF will be preserved, and the suspended activity may be resumed at the option of the instructor or the pilot. Except for the primary flight controls, controls and displays at the IOS and in the cockpit will retain their normal function during use of this feature and may be employed to change the preserved conditions. During a period of freeze, cockpit avionics displays will reflect the fixed position of the simulated aircraft but will otherwise function normally in response to operation of the controls associated with such displays.

b. Purpose and Intended Use

The primary purpose of the MF feature is to permit the interruption of the simulation so that other instructional or supporting activities may take place or to provide a break in the instruction. The secondary purpose of this feature is to provide a stable condition during periods in which the simulator is "on" but the cockpit may be unoccupied, thus allowing necessary setup or simulation modification functions to be performed through controls located at the IOS. Cockpit ingress/egress also will be possible during periods of freeze without concern for inadvertent movement of cockpit controls.

During the course of instruction, the instructor will employ the MF feature in conjunction with other instructional features. A modification to the simulation that involves a discontinuity in any parameter affecting flight will be effected only while the simulator is in a freeze status, e.g., repositioning of the simulated aircraft or substituting one external visual display scene for another (discontinuities involving visual displays will require that such displays be blanked to minimize distractions to the pilot). Instructional features that are incompatible with simulated flight under pilot control may be initiated only when the simulator is in a freeze status, e.g., Record/Playback and Demonstration. Likewise, use of the Remote Display feature, and the Harcopy feature when simultaneous copies of multiple displays are desired, can occur only when the simulator is in freeze status. Use of other features, such as Malfunction Simulation, Automatic Malfunction Insertion, and Parameter Freeze, may be initiated without respect to the freeze status of the simulator, but the effect of these features upon the simulation will be noted only when the simulation has resumed.

Although the frequency of use of the MF feature will vary as a function of the preference of the instructor, the relative skill of the pilot, and the simulated activity under way, the feature will be employed frequently. Therefore, ready access to it is important. When control of instructional activities is being exercised from the IOS, employment of the feature normally will be initiated and terminated by the instructor. When the pilot is engaged in a self-instructional activity, he may also initiate and terminate periods of freeze from the cockpit. To avoid confusion over whether the simulator is being or can be flown from the aircraft controls, the freeze status of the simulator must be made obvious to all participants in the instructional process at all times, regardless of whether its status was determined by the instructor, by the pilot, or otherwise.

c. Commonalities/Differences

1. Control functions:

Freeze Activation - Controls located at the instructor station and at the trainee station which, when activated, cause all time-dependent functions to cease. Activation of freeze also provides a clear visual indication in the cockpit and at the instructor station that such an action has been taken. The action occurs within one computer frame cycle.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Freeze Activation	X	X	X	X

FIGURE D-3

2. Functional differences:

There are no functional differences within the SFTS when freeze is activated. Activation suspends all ongoing simulation activity. While in freeze, all simulators permit modification of the aircraft's simulated position, environment, and basic configuration. All cockpit and instructor controls associated with oepration of the simulator, including instructional features, are fully operable.

3. Hardware differences:

Activation - The CH-47 FS, AH-1 FWS, and AH-64 CMS utilize lighted alternate action switches to activate freeze at both the trainee and the instructor stations.

The UH-60 FS utilizes a mushroom type (2-1/2 inches in diameter) alternate action switch at both instructor and trainee stations.

4. Advantages/disadvantages of design:

Freeze Activation. The mushroom type switch is superior to the lighted switch. It is easier to find in the dimly lit simulator interior. Additionally, during violent or radical excursions of the simualtor motion system, the mushroom switch would probably be easier to access and activate.

4. Automatic Freeze

a. Definition

Automatic Freeze (AF) is a simulator instructional feature that automatically freezes or suspends ongoing simulated activity when predetermined conditions are met. The effects upon the simulation and upon the cockpit and IOS controls of an automatically initiated freeze are identical to those of a manually initiated freeze.

b. Purpose and Intended Use

The purpose of the AF feature is to place the simulator in freeze status immediately upon the occurrence of specified events, and to do so without intervention by personnel at the IOS or in the cockpit. Three kinds of events may trigger the AF feature. They are: (1) entering a set of flight conditions that would be the equivalent of a crash in the aircraft being simulated, e.g., exceeding aircraft structural limits or impacting the surface at an excessive rate; (2) being impacted by surface-to-air or air-to-air weapons; and (3) encountering conditions that mandate placing the simulator in freeze status, e.g., preparing the simulator for an initial instructional activity or reaching the end of a period of recorded flight. Since the initiation of a freeze condition resulting from such events may not be expected, its onset must be called to the immediate attention of the instrutor and the pilot.

The simulator may normally be released from freeze status at any time through positive action by the instructor or the pilot. However, in the case of an automatically initiated freeze resulting from the entry of the simulated aircraft into crash conditions, action must be taken to remove or overcome those conditions before the period of freeze can be ended. This may be done while the simulator is in freeze status by selecting and inserting a new set of initial conditions preparatory to beginning a new training activity, thus effectively removing the aircraft from the conditions that led to the freeze. Alternatively, the instructor may elect to "override" the crash conditions and permit the flight to continue from the point of crash. Should this latter alternative be elected, the simulated aircraft would "fly out" of the crash conditions following termination of freeze.

Crash conditions may be encountered frequently in training situations in which relatively inexperienced pilots are attempting to acquire skill at tasks involving unstable flight regimes or high performance maneuvers. In these situations, crash conditions might be encountered too frequently for efficient instruction to take place. In order to avoid such inefficiencies, the instructor might "override" future crashes until pilot proficiency improves, and thus permit the simulated aircraft to "fly through" conditions that otherwise would result in a crash and the automatic initiation of a period of freeze. If the override function was selected before crash conditions were encountered, the simulated flight would continue uninterrupted, but the displays at the IOS would reflect the fact that conditions equivalent to crash had been met. The instructor would retain the option to remove the override function or to employ the Manual Freeze feature at any time.

A similar situation exists with respect to the automatic initiation of freeze status when the simulator's weapons-scoring algorithm determines that the simulated aircraft has received a lethal round (or number of rounds) from an enemy weapon, i.e., "own aircraft" has been "killed." When this occurs, the simulator will enter freeze status automatically and will remain in that status until it is ended by positive action from the IOS. As with the crash situation, in the kill situation the instructor may remove the kill conditions by selecting a new set of initial conditions and resetting the simulator for the next training exercise. Alternatively, he may override the kill conditions (including any aircraft system malfunctions that may have been simulated to indicate nonlethal hits) and, by ending the freeze status, allow flight to continue from the point of interruption. As with crash, the instructor also may elect in advance to override the AF feature with respect to the hit-kill algorithm in order to avoid too-frequent interruptions for a relatively unskilled pilot. When Override is elected in advance of the event's occurrence, the effects of being hit, other than aircraft degradation and/or freezing the simulation, will nonetheless occur, e.g., sounds and weapons signatures will occur, and scoring and status information will be displayed at the IOS. The instructor, in advance and without regard to his election concerning crash conditions, may elect to override or not override kill conditions. Conversely, he may do the same with respect to crash conditions.

The other events which automatically initiate freeze status relate to administrative aspects of the simulator instructional process and provide an interruption in the simulation at points at which a decision must be made concerning the next instructional activity. No AF override function is appropriate with respect to these events, because their occurrence indicates a choice point at which a different activity must be initiated if the simulation is to continue. Such an event occurs when the simulator is initially made ready for use at the beginning of a period of instruction and at the end of a segment of recorded flight, e.g., upon completion of a Demonstration or a selected interval of Record/Playback.

c. Commonalities/Differences

1. Control functions:

Activation - This feature is activated automatically when predetermined conditions are met. The result of an automatic freeze are identical to those of a manually initiated freeze. It is not under manual control.

Crash Override - This function enables the instructor to avert a crash condition. The simulator will fly through the crash condition, or the instructor can activate crash override after a crash occurrence and fly away from it.

Kill Override - This function enables the instructor to avert a threat weapons kill algorithm. The simulated aircraft will fly thorugh the condition; however, cockpit sounds and visual indications of a hit are still present.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Activation	X	X	X	X
Crash Override	X	X	X	X
Kill Override	X			

FIGURE D-4

2. Functional differences:

Kill Override - The AH-64 CMS contains the simulation of a realistic threat environment to include interactive hostile weapons and radar emitters. The threat is controlled by automatic target engagement exercises and a sophisticated threat algorithm. To enable the instructor to manage and control the training process, the Kill Override control was provided.

The CH-47 FS, AH-1 FWS, and UH-60 FS include visual and audio cues for threat weapons activity but not hits that cause systems malfunctions or catastrophic failures requiring emergency landings or crashes. Consequently, this function is not applicable to those simulators.

3. **Hardware differences:**

Kill Override - A lighted alternate action switch has been added to the AH-64 CMS instructor control panel to provide this control.

4. Advantages/disadvantages of design:

All of the SFTSs have automatic freeze instructional features and crash override controls. The need for the Kill Override is unique to the AH-64 CMS because of the interactive threat environment.

5. Parameter Freeze

a. Definition

Parameter Freeze (PF) is a simulator instructional feature that enables the instructor to freeze one or more of the simulator flight parameters to its current value. When a parameter is in freeze status, all other parameters will be unaffected. All simulator performance and the displays at the IOS will reflect the fixed value of the frozen parameter, however.

The parameters that can be frozen by the instructor are limited to those provided in the simulation. These parameters will include aircraft position, individual rates of directional and angular movement, orientation in space, and fuel and expendable stores on board. The status of all frozen parameters will be indicated prominently on relevant IOS displays and in all records of measured pilot performance.

b. Purpose and Intended Use

The primary purpose of the PF feature is to enable the instructor to reduce the difficulty to the pilot of the task being performed. Using the PF feature, this could be done by freezing one or more parameters of flight, thus reducing the number of parameters demanding the pilot's attention. Such an approach might be employed to simplify aircraft control when a pilot is experiencing difficulty developing the complex skills required to fly the simulated aircraft, or while the pilot acquires skills at associated tasks such as tracking a missile on a target or learning to operate on-board avionics and associated displays. When pilot performance is being measured automatically, use of the PF feature will be displayed prominently in all data displays and recordings to indicate that the task has been made easier to perform.

A secondary purpose of the PF feature is to facilitate the administration of training involving expendable resources, i.e., fuel. By freezing these parameters,

training can proceed without interruption for the purpose of restoring expended resources. The effect would be to provide an inexhaustible supply of fuel.

A parameter may be frozen without respect to whether the simulator is in freeze status. Thus, a parameter frozen while the simulator is in freeze status will remain in freeze status when the simulator freeze is ended. While the feature will be employed sparingly, timing of the initiation of a period of freeze for a selected parameter may be important to the instructor, and the process cannot be lengthy or difficult.

c. Commonalities/Differences

1. Control functions:

Parameter Freeze Activation - This function enables the instructor to select one or more simulated aircraft parameters (flight, position, configuration) and freeze them at their existing condition.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Parameter Freeze Activation	X	X	X	X

FIGURE D-5

2. Functional differences:

Airspeed/Altitude Freeze - The CH-47 FS and the UH-60 FS have a separate control to enable the flight instructor to freeze the indicated parameter without accessing the CRT when preparing demonstrations.

Vertical Speed/ Turn Rate Freeze - The CH-47FS and the UH-60 FS have this control to assist the flight instructor to freeze the indicated parameter without accessing the CRT when preparing fly in demonstrations.

3. Hardware differences:

Airspeed/Altitude
Freeze - The CH-47FS and UH-60 FS have a discrete lighted alternate action switch (A/S ALT FREEZE) located on the Auxiliary Control Panel in the trainee station to activate/deactivate these two freeze parameters simultaneously.

Verticle Speed/
Turn Rate Freeze - The CH-47 FS and UH-60 FS have a discrete lighted alternate action switch (CLIMB TURN R) located on the Auxiliary Control Panel in the trainee station to activate/deactivate these freeze para-meters simultaneously.

4. Advantages/disadvantages of design:

In the CH-47 FS and the UH-60 FS, the Airspeed/Altitude Freeze and the Vertical Speed/Turn Rate Freeze controls, along with several other controls, are installed on an Auxiliary Control Panel. This panel is installed on the aft console between the pilot's and copilot's seat. The Auxiliary Control Panel includes controls which help the flight crew to record demonstrations from the trainee compartment when no one occupies the instructor station. They are useful in a side-by-side aircraft configuration where a copilot can use them while a pilot flies the aircraft.

The AH-64 CMS and AH-1 FWS simulate tandem-seated aircraft, with each seat isolated to its own cockpit. Thus, only one pilot occupies the cockpit. Demonstrations are prepared in these simulators with an instructor at the instructor station. Thus, separate controls to freeze airspeed, altitude, vertical speed, and turn rate were not considered necessary, since the functions involved can be performed through CRT/keypad controls.

6. Demonstration

a. Definition

Demonstration (Demo) is a simulator instructional feature that consists of a prerecorded aircraft maneuver, or series of contiguous maneuvers, that provides a model of the desired performance of the maneuver being demonstrated. The Demo reproduces all simulated flight conditions and aircraft performance that occurred when the maneuver was originally recorded, including appropriate actuation of cockpit

instruments, indicators, and flight controls; motion system movement; visual display scenes; and mechanical and aerodynamic sounds. A Demo includes a synchronized audio briefing, explanation, and instructional commentary designed to facilitate the pilot's subsequent performance of the maneuver.

The content of a Demo is not necessarily limited to execution of the maneuver(s) being demonstrated. A Demo may include repetitions of the entire maneuver or of any one or more of its segments, segments presented in slow time, and pauses, each with unique instructional commentary, whenever such variations in format of presentation may facilitate an understanding by the pilot of the associated performance requirements.

Demos may be divided into segments that correspond to significant parts of the maneuver being demonstrated or to events in the Demo itself. Each such segment is independently addressable from the IOS. Thus, each segment provides a "mini Demo" that addresses a particular aspect or portion of the maneuver being demonstrated.

b. Purpose and Intended Use

The purpose of the Demo feature is to provide standardized instruction in the performance of difficult and/or complex aircraft maneuver or series of contiguous maneuvers. The content and format of that instruction may vary significantly from one Demo to another, but Demos normally illustrate idealized performance, identify the significant cues and discriminations the pilot must learn to make in executing a maneuver, and provide other instructional commentary that may facilitate task mastery. A properly prepared Demo will aid the pilot in the acquisition of both knowledge and skills associated with performance of the maneuver demonstrated.

Demos normally will be used by the instructor to introduce a new maneuver to the pilot, and the pilot will observe the entire Demo without interruption before attempting to perform the maneuver in the simulator. The instructor might wish to repeat all or a portion of the Demo immediately, or after the pilot has attempted to perform the maneuver. Alternatively, the instructor might re-present the Demo or one or more of its segments for the further instruction of a pilot who may find the maneuver particularly difficult to understand or to perform correctly. The instructor may elect to re-present only a segment on which the maneuver is recorded in slow time or in which a particular explanation is included, or he may repeat the entire Demo or a segment of it with the accompanying instructional commentary off so that he can provide his own commentary.

c. Commonalities/Differences

1. Control functions:

Demonstration Activation - Permits selection and presentation of a previously developed demonstration. Demonstration selection and activities must take place when the simulator is in freeze status.

Segment Select - Permits entry to demonstrations at intermediate locations (segements) within the demonstration.

Audio Off - Enables and disables audio during monitoring of demonstration.

Terminate - This function permits stopping the demonstration at any point after its initiation and short of completion. Terminate is initiated with FREEZE.

Flyout - This function permits termination of the demonstration at any point and resumption of free flight from that point.

Condition Reset - This function permits termination of the demonstration at any point, reset to a previously stored set of conditions, and resumption of free flight from that point.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Demo Activation	X	X	X	X
Segment Select	X	X	X	X
Audio Off	X			
Terminate	X	X	X	X
Flyout	X	X	X	
Condition Reset	X			

FIGURE D-6

2. Functional differences:

Activation - Figure D-6-1 depicts the functional differences of the various SFTS demonstration programs.

FUNCTIONAL DIFFERENCES				
FUNCTIONAL ITEM	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Number of Demos	20	20	20	24
Maximum Time per Demo (min)	5	15	30	30
Total Available Disc Time (min)	200	300	300	480
Maximum Segments per Demo	8	10	10	10

FIGURE D-6-1

Segment Select - All of the SFTSs permit accessing individual segments (maneuvers) within demonstrations. However, the AH-64 CMS is the only one to provide synchronized audio commentary when selecting a demo segment. All of the others lose the audio commentary unless the demo is activated from the beginning.

Audio Off - The AH-64 CMS is the only SFTS with control over this function.

Terminate - All of the SFTSs have provisions to terminate demonstrations at any point prior to completion. However, subsequent training activities are determined by availability of other control functions. The AH-64 CMS permits flyout, condition reset, and reinitialization to resume training.

The CH-47FS and AH-1 FWS permit flyout and reinitialization to resume training. In the AH-60 FS, a new initial conditions set must be selected in order to resume training.

Flyout - The AH-64 CMS, CH-47 FS, and AH-1 FS permit flyout. The UH-60 FS does not have this capability.

Condition reset - This function is unique to the AH-64 CMS. The instructor may store a single set of conditions at

anytime prior to initiation of demonstrations and, upon completion of the demonstration, return to that set of conditions.

3. Hardware differences:

Activation and Segment Select - The CH-47 FS, AH-1 FWS, and UH-60 FS all employ three sets of digital thumbwheels to select demonstration numbers. Activation/deactivation of specific demonstations is accomplished by depressing discrete INSERT or DELETE lighted switches after the demo number has been selected.

The AH-64 CMS utilizes the instructor's keypad in conjunction with a CRT page, to select and activate the desired demonstration.

Flyout - All of the SFTSs have discrete lighted switch controls for FLYOUT, and with the exception of the UH-60 FS, these controls function with the Demonstration and Record/Playback instructional features. The UH-60 FS flyout feature does not function during demonstrations.

Condition Reset - This function and the discrete lighted switch through which it is activated are unique to the AH-64 CMS. It is described elsewhere in this report.

4. Advantages/disadvantages of design:

The demonstration termination capabilities included in the AH-64 CMS provide more flexibility to the instructor for managing and controlling the training process. The need to reinitialize the UH-60 FS is a limitation in that simulator.

The digitized voice system in the AH-64 CMS provides synchronized voice commentary at any point in the demonstration.

7. Demonstration Preparation

a. Definition

Demonstration Preparation (Demo Prep) is a simulator instructional feature that enables a simulator instructor to prepare a Demonstration (Demo) for repeated use during subsequent periods of pilot training.

b. Purpose and Intended Use

The purpose of the Demo Prep feature is to permit Demos to be prepared by recording a period of performance in the simulator, modifying that recording to enhance its instructional value, and adding an expository or instructional commentary. The skills required to prepare a Demo using this feature are those normally found among simulator instructors who are pilots, and no additional technical training or computer programming skills are required. Nevertheless, it is expected that only designated instructors will prepare Demos in order that control may be exercised over their content and format.

Recording a Demo in the simulator will normally be preceded by the development of a scenario for the Demo. The scenario will identify the simulated conditions under which the maneuver(s) of interest will be flown, the number of repetitions of all or designated portions of the maneuver that are to be included in the completed Demo, where Pauses are to appear, and which segments are to be presented in slow time. The scenario also will identify the beginning of each Demo segment that is to be directly accessible by the instructor. A script of the planned instructional commentary will be prepared for the scenario. The script will be edited to assure that proper timing will be maintained between the content of the Demo and the commentary.

Following development of the scenario with its accompanying audio commentary, the Demo described in it will be developed by flying the simulated aircraft through the maneuver or series of maneuvers to be demonstrated while the flight is being recorded. While making the recording, the instructor (with the assistance of a second instructor located in the cockpit) would make use of the simulator's other instructional features such as Manual Freeze, and Store/Reset Current Conditions, as often as necessary to obtain a "model" performance of the maneuver being flown. This process may be repeated until the instructor is satisfied that the maneuver has been flown to the required standards. If the scenario requires that the Demo inlcude more than a single repetition of the maneuver, as usually will be the case, the recording process will be repeated as many times as may be required.

Upon completing the recording of the maneuver, the instructor will "edit" it in accordance with the scenario by inserting pauses when extended instructional commentary might be required or by "stretching" to slow time parts of the maneuver which occur too rapidly in real time for the pilot to be able to see important task interrelationships. He then would add Demo segment identifiers that will permit

direct access to the beginning of individual segments when the Demo is employed in the instructional process.

Finally, using the script prepared for that purpose, the instructor will add the prepared instructional commentary to the recorded Demo. Recording the audio, which would normally be done while the newly prepared Demo is being replayed and monitored, will require careful attention--and possibly several practice trials--to synchronize the commentary with the instructional events being commented upon.

Because humans have limited attention spans and short-term recall abilities, the more effective Demos will tend to be relatively brief. The subject matter of Demos will consist of complex individual maneuvers or rapidly occuring series of maneuvers of which verbal descriptions alone might not provide enough information for pilots to learn rapidly to perform them. It is not expected that Demos will be prepared to illustrate mission segments in which individual maneuvers are separated by extended periods of relatively simple aircraft control tasks. For these reasons, most Demos, including those which contain Pauses and Slow Time segments, will be brief, i.e., of less than five minutes duration. Long Demos would be counterproductive in most instances and should not be prepared.

c. *Commonalities/Differences*

1. Control functions:

Enable - Controls at the instructor station and in the computer room that permit access to the demonstration preparation programs.

Initialize - Permits the instructor to establish a set of simulated conditions to support the demonstration to be developed.

Record - Cause the flight maneuver to be demonstrated to be stored or recorded.

Edit Pause - Permits the insertion of periods of pause into the recorded flight demonstration.

Edit Slowtime - Permit "stretching" the real time flight recording to one half real time.

Segment Identification - Permit the instructor making the demonstration to flag specific points in the flight recording for segment identification and subsequent recall.

Edit Audio - Permits insertion of audio commentary to the flight recording.

Store/Terminate - Permits permanent storage of the compelted demonstration and termination of the demonstration preparation status of the simulation.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Enable	X	X	X	X
Initialize	X	X	X	X
Record	X	X	X	X
Edit Pause	X		X	X
Edit Slowtime	X		X	X
Segment Identification	X	X	X	X
Edit Audio	X	X	X	X
Store/Terminate	X	X	X	X

FIGURE D-7

2. Functional differences:

Enable - The CH-47 FS, AH-1 FWS, and UH-60 FS permit direct access to the demonstration preparation program from the instructor station.

The AH-64 CMS requires a coded instruction to be addressed from the computer room prior to accessing the demonstration preparation program from the instructor station.

Edit Pause - The CH-47 FS does not have the capability for inserting pauses into the recorded flight demonstartion.

The AH-1 FWS and UH-60 FS can only insert pauses into the recorded flight demonstation if flags are placed on the disc while the flight is being recorded.

The AH-64 CMS permits inserting pauses in the recorded flight demonstration after it is completed and is being monitored (edited) during a replay.

Edit Slowtime - The CH-47 FS does not have the capability for inserting slowtime into the recorded demonstration.

The AH-1 FWS and UH-60 FS can only insert slowtime into the recorded flight if flags are placed on the disc while the flight is being recorded.

The AH-64 CMS permits inserting slowtime in the recorded flight demonstration after it is completed and is being monitored during replay.

Segment Identification - With the CH-47 FS, AH-1 FWS, and UH-60 FS, segment identifiers must be inserted in the recorded flight demonstration while the flight is being recorded.

The AH-64 CMS permits inserting segment identifiers in the recorded flight demonstration after it is complete and is being monitored during replay.

3. Hardware differences:

The CH-47 FS, AH-1 FWS and the UH-60 FS incorporate discrete lighted switches at the instructor station to be used to activate the control functions associated with demonstration preparation.

The AH-64 CMS utilizes the instructor's keypad and a menu-type CRT page display to activate and control the functions associated with demonstration preparation.

4. Advantages/disadvantages of design:

The AH-64 CMS, AH-1 FWS, and UH-60 FS demonstration preparation capabilities are similar. Detailed structuring of scenarios prior to preparation in the AH-1 FWS and UH-60 FS could possibly provide comparable demonstrations to those possible with the AH-64 CMS. With the capability of the AH-64 CMS to edit demonstration (i.e, to insert pause and slow time segments, and to add and receive instructional commentary) after the flight has been recorded, the instructional staff has much more flexibility in developing demonstrations, and the level of effort required to develop a satisfactory demonstration should be significantly reduced in this device.

8. Malfunction Simualtion

a. Definition

Malfunction Simulation (MS) is a simulator instructional feature that enables the instructor to fail, partially or totally, a simulated aircraft component or to introduce an abnormal aircraft condition. When such a failure is inserted into the simulation, the consequences will duplicate the consequences of a corresponding failure in the aircraft simulated. Actions taken by the pilot in the simulator following insertion of a failure will have the same consequences as would be experienced under corresponding circumstances in the aircraft. The malfunctions that can be simulated will consist of component failures or abnormal conditions likely to occur during operation of the aircraft on the ground or in flight during the useful life of the aircraft, and for which an appropriate response by the pilot is required in order to complete a mission, avoid further aircraft degredation, or continue flight until a landing can be made. The instructor may insert or remove a simulated malfunction, but he may not affect its programmed chracteristics.

b. Purpose and Intended Use

The purpose of the MS feature is to enable the instructor to simulate the occurrence of component malfunctions and failures so that the pilot may be trained to determine that an abnormal condition has occurred, identify the condition, and take the prescribed corrective or compensating action. Since the simulator provides a safe environment in which such training can take place, it will be used frequently and in conjunction with all other instructional features of the simulator not involving recorded performance, and it will provide the only environment in which training associated with the most hazardous malfunctions can take place. For this reason, malfunction-compensating skills developed in the simulator must transfer intact and without further training to the aircraft. All cues that are associated with the malfunction in the aircraft and are detectable by the pilot are necessary to such transfer and must be represented in the simulator.

c. Commonalities/Differences

1. Control functions:

Selection -	Permits the identification and selection of malfunctions to be inserted or deleted.
Insertion -	Permits selected malfunctions to be inserted into the simulation.

Deletion - Permits deletion or deactivation from the simulation of selected malfunctions.

Clear - Permits deletion or deactivation from the simulation of all previously inserted malfunctions simultaneously.

COMMONALITY/DIFFERENCE OF CONTROL FUNCTIONS				
CONTROL FUNCTIONS	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Selection	X	X	X	X
Insertion	X	X	X	X
Deletion	X	X	X	X
Clear	X	X	X	X

FIGURE D-8

2. Functional differences:

Activation/Deactivation - Figure D-8-1 depicts the functional differences among the SFTS malfunction features.

FUNCTIONAL DIFFERENCES				
FUNCTIONAL ITEM	AH-64 CMS	CH-47 FS	AH-1 FWS	UH-60 FS
Total Number of Malfunctions	225	200	131	262
Number Active at a Time	5	10	5	9

FIGURE D-8-1

3. Hardware differences:

Selection - The CH-47 FS, AH-1 FWS, and UH-60 FS all employ three sets of digital thumbwheels to select malfunctions by numbers. The instructor's keypad is used to call up the malfunction display page on the CRT so that malfunction numbers may be determined.

With the AH-64 CMS, the instructor's keypad is used to call up the malfunction display on the CRT and to insert the selected malfunction by number.

Insertion - In the CH-47 FS, AH-1 FWS, and UH-60 FS, activation of a specific malfunction is accomplished by depressing a discrete INSERT lighted switch after its number has been inserted.

The AH-64 CMS utilizes the instructor's keypad to activate the selected malfunctions.

Deletion - The CH-47 FS, AH-1 FWS, and UH-60 FS employ the digital thumbwheels with the malfunction number selected and a discrete DELETE switch to deactivate malfunctions singularly.

The AH-64 CMS utilizes the instructor's keypad to deactivate malfunctions individually.

Clear - The CH-47 FS, AH-1 FWS, and UH-60 FS have discrete lighted MASTER MALFUNCTION CLEAR switches which will deactivate all active malfunctions simultaneously.

The AH-64 CMS also has a discrete lighted switch (REMOVE ACTIVE MALFUNCTIONS) which deactivates all active malfunctions simultaneously.

4. Advantages/disadvantages of design:

For direct activation or deactivation of malfunctions, the AH-64 CMS uses the instructor keypad and the other SFTSs use thumbwheels and discrete switch. If a CRT alphanumeric listing is required to identify the desired malfunction, the AH-64 CMS instructor may display the malfunction lists on the CRT via the same keypad used to enter the malfunction. A minor modification to the numerical sequence being entered will provide these data. However, on the other SFTSs, if these same data are required, the instructor must use his instructor keypad for the required display in addition to the thumbwheels to enter the malfunction.

A feature that is of questionable training value is the number of malfunctions active simultaneously in the CH-47 FS and UH-60 FS. With five active malfunctions, a student pilot's manageable workload is heavily taxed to maintain aircraft control. To permit activation of 9 or 10 malfunctions may overburden the student and produce an unmanageable training environment.

9. Store/Reset Current Conditions

a. Definition

Store/Reset Current Conditions (S/R) is a simulator instructional feature that permits the simulation to be returned or reset to a set of conditions that existed at an earlier point in time. The conditions to which the simulation would be reset using this feature would have been selected when the simulator was initialized, or at the time of their occurrence during an instructional activity, and recorded or stored at that time for subsequent use. Selecting and storing such conditions will not interrupt or otherwise affect ongoing simulator activities. The stored conditions would be retained until replaced by other stored or designated initial conditions. Reset to a set of stored conditions can occur repeatedly.

b. Purpose and Intended Use

The primary purpose of the S/R feature is to permit a pilot to return (or to be returned) to a previously encountered set of simulated conditions in order that he may repeat a maneuver or flight segment that he attempted earlier. The feature might also be used to provide a quick-reset capability that would enable an instructor or the pilot to reset the simulated aircraft to a previously designated set of initial conditions with minimum effort. A secondary purpose of the S/R feature is to facilitate the development of coherent sets of initial conditions that can be retained for use during subsequent periods of instruction.

The S/R feature provides a means of increasing the efficiency of the simulator instructional process by enabling the rapid and easy reestablishment of the exact conditions needed for a particular instructional activity. Thus, if the existent conditions associated with the beginning of a maneuver or maneuver segment through which the simulated aircraft may be flying are stored, the aircraft can be reset to those conditions without having to repeat the process of flying to them.

The storage of such conditions is accomplished through controls located at the IOS and in the cockpit. The existent conditions of the simulation may be stored without respect to other instructional activities, to the freeze status of the simulator, or to the position of any other IOS or cockpit controls. However, because operation of the S/R controls in the cockpit may be difficult while flying the simulator, the pilot will normally place the simulator in freeze status before exercising the Store function. The Store function may be exercised repeatedly, but the Reset function will always reset the simulated aircraft to the conditions existent at the most recent time the

Store function was exercised. There is no restriction on the frequency of use of the Reset function.

During an instructional period in which the Store function has not been exercised, exercise of the Reset function will reestablish the simulator initial conditions most recently selected through controls associated with the initialization process. Each selection of an alternate set of simulator initial conditions during an instructional period will automatically result in the loss of previously stored conditions. Subsequent exercise of the Reset function before the Store function is exercised will result in the reestablishment of the most recently selected initial conditions set. Thus, activation of the Reset function will always restore the most recently selected set of simulation conditons, whether they were selected by exercise of the Store function of the S/R feature or through the simulator initialization process.

As with the Store function, the Reset function may be exercised from the IOS or the cockpit. Thus, a pilot responsible for his own instruction would be able to increase the efficiency of that instruction by frequently resetting to conditions appropriate to the particular task he might be practicing.

While the Store function can be exercised without regard to the freeze status of the simulator, the Reset function can be exercised only while in freeze status. This status is necessary during reset because of the likely discontinuity of the parameters of simulation involved in the simulated physical displacement of the aircraft.

Use of the S/R feature to develop initial condition sets for use during subsequent periods of instruction is a function that will take place when instructional activities are not in progress. When new or revised initial condition sets are required, they will be established by "flying to" the desired conditions, storing them, and entering a freeze status. The stored conditions would then be transferred into "permanent" storage in designated memory locations. In order to maintain control over the content of initial condition sets, however, designation of a memory location and transfer of the stored condition into permanent storage is a program development function and cannot routinely be accomplished through controls located at the IOS.

10. Remote Display

a. Definition

Remote Display (RD) is a simulator instructional feature that permits alphanumeric and graphic data displayed on an IOS CRT to be displayed simultaneously

to the pilot in the cockpit. The remote display will appear on a display provided for that purpose or on an existing display provided primarily for other uses (e.g., visual system, HUD, or sensor scope).

b. Purpose and Intended Use

The purpose of the RD feature is to enable the instructor at the IOS and the pilot in the cockpit to view displayed information simultaneously. The feature will be employed to facilitate communication between the instructor and the pilot, particularly when the communication involves reference to graphic or symbolic information. Any single CRT display reflecting pilot or simulated vehicle performance available at the IOS may be remoted for the pilot's viewing while it is being displayed at the IOS.

The RD feature will normally be employed when the simulator is in freeze status. It cannot be used when the simulated aircraft is being controlled by the pilot in the cockpit, since its use at such times could interfere with ongoing simulated activities. During playback of a previously recorded segment of simulated flight (i.e., Record/Playback or Demonstration), however, the instructor may employ the RD feature to enable the pilot to observe status information displayed on an IOS CRT and to correlate that information with vehicle performance.

11. Automatic Malfunction Insertion

a. Definition

Automatic Malfunction Insertion (AMI) is a simulator instructional feature that automatically inserts malfunctions or failures of simulated aircraft components in response to previously selected conditions expected to occur during an instructional activity. These contingent conditions include events such as reaching a specified altitude or airspeed, releasing a weapon, exceeding a time limit, or any combination of such events. When the specified insertion contingencies have been met, the malfunction will occur in the manner programmed for it without instructor intervention. The contingencies which "trigger" the insertion of each malfunction may be partially or totally unique. The AMI feature is organized into instructional exercises consisting of a limited number (e.g., up to 10) preselected malfunctions each.

b. Purpose and Intended Use

The purpose of the AMI feature, in contrast to the nonautomatic Malfunction Simulation feature in which malfunctions are inserted manually by the

instructor, is to cause selected malfunctions to be inserted automatically upon the first occurrence during a simulated flight of previously specified events. The reduced reliance upon an instructor to initiate emergency procedures training will permit a relatively skilled pilot to practice selected emergency procedures when a simulator instructor may not be available to administer such training. An additional purpose of the AMI feature is to provide a greater degree of standardization in the selection and insertion of malfunctions during training than would be possible if it were necessary to rely solely upon various instructors to select and insert them. The increased standardization will facilitate the assessment of pilot skill in responding to malfunctions and will permit an increased degree of control over the content of training, i.e., over the simulated malfunctions to which each pilot is exposed during instruction.

The AMI feature will be used during advanced or continuation training activities to aid previously trained pilots in the maintenance of their skills related to recognizing and coping with aircraft malfunctions. The feature may be used with a simulator instructor in attendance to provide instruction and criticisms as may be appropriate. Alternatively the use of the feature permits a pilot to review his emergency skills in a "self-study" or review mode. In any event, the AMI feature will be used when the primary purpose of the training activity is to conduct emergency procedures training for pilots who are already familiar with the malfunctions involved, or to provide a standardized situation in which pilot responses to malfunctions can be evaluated. It will not be used to introduce pilots to malfunctions or in conjunction with other training activities for relatively unskilled pilots.

12. Automatic Malfunction Insertion Exercise Preparation

a. Definition

Automatic Malfunction Insertion Exercise Preparation (AMI Prep) is a simulator instructional feature that enables a simulator instructor to prepare an AMI exercise for repeated use during subsequent periods of instruction. An AMI exercise consists of simulated aircraft malfunctions with single or multiple automatic insertion conditions specified for each.

b. Purpose and Intended Use

The purpose of the AMI Prep feature is to permit AMI exercises to be prepared by selecting a set of malfunctions to be simulated during a subsequent instructional activity and identifying specific contingencies which, if met during such

instruction, will "trigger" the insertion of each of the selected malfunctions without further instructor involvement. The skills required to prepare an AMI exercise using this feature are those normally found among simulator instructors who are pilots, and no additional technical training or computer programming skills are required. Nevertheless, it is expected that only designated instructors will prepare such exercises in order that exercise content may be controlled.

Preparation of an AMI exercise will be preceded by the development of a training mission profile or scenario to be used in conjunction with the particular malfunctions of interest. This scenario will provide a context within which the intended malfunction instructional activities can take place. It will also permit the instructor to determine when malfunctions should be inserted to be of most instructional value, and the insertion contingencies that are both probable as to occurrence and realistic as to the circumstances of occurrence. An AMI exercise will involve a maximum of approximately ten malfunctions.

In conjunction with the development of the scenario, the instructor will identify an initial conditions set to be used with the scenario. This is important because using a specified initial conditons set with a particular AMI exercise provides an additional degree of standardization for the planned malfunction instruction. If used with another set, the occurrence of a particular malfunction would be less predictable, and standardization of training would suffer. Where standardization may not be a concern, however, such as during practice sessions when an instructor may not be present, other initial conditions sets could be used with the AMI exercise.

Following development of a scenario which identifies the malfunctions to be included in the exercise and specifies the contingencies to be used to trigger insertion of each malfunction, the exercise itself must be prepared. This is done interactively with the simulator through controls and displays located at the IOS. Using a programmed question and answer format, the instructor will identify one of the available simulated malfunctions and will specify the insertion contingencies to be associated with it. The contingencies will be specified in terms of arithmetic operations (equal to, greater than, less than) and logical operators (AND and OR) on parameters such as flight variables, time, position, preceding malfunction insertions, lethality algorithms, and events such as weapons release and gear extension. In specifying these contingencies, the instructor will select one or more parameters from among a set of programmed parameters, specify the logical operator involved (if more than one contingency parameter is selected), and "assemble" the contingencies desired

to trigger each target event. Up to a minimum of five different parameters can be involved in triggering each event, although one or two will be sufficient in most instances. These exercise assembly activies will be repeated for each target event to be included in the exercise.

When completed, the AMI exericse may be reviewed by inspecting a display at the IOS. The display will identify the initial conditions set or sets that are appropriate for use with the exercise, the malfunctions included in the exercise, and and the triggering parameters and designated operators associated with each. The flight profile appropriate to the exercise also will be indicated.

After assembling an AMI exercise in the manner described, it will be stored with other exercises and made addressable for subsequent use during simulator instructional activities. The display of the assembled exercise will be available for subsequent use by instructors as an aid when the exercise is being used.

13. Automatic Flight

a. Definition

Automatic Flight (Auto Fly) is a simulator instructional feature that "flies" the simulator for the copilot/gunner (CPG) when the CPG cockpit is operated in the independent mode. When engaged, the Auto Fly feature will fly the CPG through a pre-recorded flight path, aircraft maneuver, or series of contiguous maneuvers. When this feature is in use, CPG cockpit instrument and indicator activation, motion system movement, visual display scenes, and mechanical and aerodynamic sounds will occur just as if the simulator were being flown in the integrated mode of operation.

b. Purpose and Intended Use

The purpose of the Auto Fly feature is to compensate for the missing portions of the simulator and the flight control activities of the pilot when the CPG cockpit is operated in the independent mode. The Auto Fly will perform all required flight control tasks and allow the CPG to concentrate on gunner tasks. While the Auto Fly feature is in use, is in Auto Fly, the CPG will have full access to and control over all sighting, sensor, and weapons systems normally available in the CPG cockpit, and will be able to detect, identify, and engage targets encountered along the recorded flight path. At predetermined firing positions, the Auto Fly feature can bring the simulated aircraft to a hover above surrounding masking cover, hold that position, and then return the aircraft to the masked position. Deviation from the recorded flight path will not be permitted.

14. Automatic Flight Preparation

a. Automatic Flight Preparation (Auto Fly Prep) is a simulator instructional feature that enables a simulator instructor to prepare an Auto Fly flight profile for repeated use during subsequent periods of training.

b. Purpose and Intended Use

The purpose of the Auto Fly Prep feature is to permit the recording of flight profiles that can be employed with the CPG cockpit when it is operating in the independent mode. The skills required to prepare and Auto Fly profile using this feature are those normally found amoung simulator instructors who are pilots, and no additional technical training or computer programming skills are required. Nevertheless, it is expected that only designated instructors will prepare Auto Fly segments in order that control may be exercised over their content and format.

Preparation of an Auto Fly recording will normally be preceded by the development of a scenario for the flight profile to be recorded. Development of the scenario will include specifications of the simulated conditions under which the flight path and maneuvers of interest will be flown, the planned route of flight, and the requirements for instructions or other communciations to the CPG during the flight.

Following development of the scenarios, the flight profile will be recorded by flying the simulated aircraft through the maneuvers indicated. As in the case of the Demonstration Preparation feature, while making the recording the instructor may make use of the simulator's other instructional features, such as Manual Freeze and Store/Reset Current Conditions, as often as necessary to obtain a "model" performance of the desired flight profile. This process may be repeated until the instructor is satisfied that each segment of the profile has been flown to the required standards.

Upon completing the task of recording the flight profile, the instructor will add segment identifiers that will permit direct access to the recording and to the beginning of its individual segments when the Auto Fly feature is employed in the instructional process.

15 Target Engagement Exercise

a. Definition

Target Engagement Exercise (TEE) is a simulator instructional feature that automatically inserts events associated with the engagement of hostile targets in

response to performance of the trainees. The events to be inserted include initiation of target movement, target weapons release, activation of hostile radar, and own-aircraft malfunctions that could result from hostile activity. The trainee performances which trigger such events include reaching a specified altitude, duration of exposure to a target, coming within a predetermined range of a target, releasing a weapon, exceeding a time limit, or any combination of such events. When the specified insertion contingencies have been met, the target event will occur in the manner programmed for it without instructor intervention. The contingencies which trigger the insertion of each event may be partially or totally unique. The TEE is organized into instructional exercises consisting of a limited number (E.G., up to 15) preselected events each.

b. Purpose and Intended Use

The purpose of the TEE feature is to provide effective target engagement training in the simulator through the automatic initiation of target activity in response to pilot and CPG performance. The use of the TEE feature will reduce reliance upon an instructor to initiate target activity and related events, thus permitting him to attend to coaching and other instructional tasks during engagement training. An additi nal prupose of the feature is to provide a greater degree of standardization in the presentation of typical threat situations during training than would be possible if it were necessary to rely solely upon various instructors to select and insert them. The increased standardization will permit an increased degree of control over the content of training, i.e., over the simulated hostile events to which each pilot is exposed, and will facilitate the assessment of pilot skill in responding to such events.

Normally, a Target Engagement Exercise will be used with pilots and/or CPGs who are already familiar with procedural aspects of operation of the aircraft and its sensor and weapons systems. When target engagement training or practice is required, the instructor will select a previously prepared exercise and insert it into the simulation. Unless the simulated aircraft is already in the appropriate portion of the visual gaming area as a consequence of prior activity, an initial conditions set that will place it in that area also must be inserted. If training is being conducted in the independent mode of simulator operation and an Automatic flight recording is to be used, the instructor must select a recording that is compatible with the Exercise rather than an initial condition set. Insertion of an Exercise will automatically activate the target sites associated with it (and deactivate any previously activated

sites), so no further effort will be required of the instructor to set up the simulator for the intended target engagement training.

An example Target Engagement Exercise event would be a designated target initiating a radar scan and lock-on, followed by release of a missile, contingent upon line of sight exposure of own-ship to that target for a period of two seconds while within a range of 3,000 meters. A second event, contingent upon the occurrence of the first, elapse of missile travel time, and continued line of sight exposure, would be a simulated near miss to own-ship (light flash outside cockpit canopy accompanied by sound) resulting in insertion of right engine oil pressure loss (a malfunction). Another example event would be initiation of movement by another target following release of an own-ship missile and the prior occurrence of the event described above.

Once an instructional activity that contains a Target Engagement Exercise is initiated, it will continue, with target activity and associated events occurring automatically as the contingent conditions associated with each are met. Instructor station displays will be updated automatically to reflect activation of target sites when the exercise is inserted and the performance of the pilot and/or CPG as the engagement progresses. Controls and other instructional features normally available during simulator instruction (Freeze, Record/Playback, Hardcopy, etc.) will be available for use during use of the TEE feature.

16. Target Engagement Exercise Preparation

a. Definition

Target Engagement Exercise Preparation (TEE Prep) is a simulator instructional feature that enables a simulator instructor to prepare a Target Engagement Exercise for repeated use during subsequent periods of instruction. A Target Engagement Exercise consists of simulated target activities with single or multiple automatic insertion conditions specified for each.

b. Purpose and Intended Use

The purpose of the TEE Prep feature is to permit Target Engagement Exercises to be prepared by selecting a set of target events to be simulated during a subsequent instructional activity and identifying specific contingencies which, if met during such instruction, will "trigger" the insertion of each of the selected events without further instructor involvement. The skills required to prepare a TEE using this feature are those normally found among simulator instructors who are pilots, and no additional technical training or computer programming skills are required.

Nevertheless, it is expected that only designated instructors will prepare such exercises in order that exercise content my be controlled.

Preparation of a TEE will be preceded by the development of a tactical situation description or scenario. This scenario will provide a context within which the intended target engagement instructional activities can take place. It will also permit the instructor to determine which target sites should be activated, what target should be placed at each activated site, when target events should be inserted to be of most instructional value, and the insertion contingencies that are both probable as to occurrence and realistic as to the circumstances of occurrence. A TEE will involve a maximum of approximately 15 target events.

In conjunction with the development of the TEE, the instructor will identify an initial conditions set or Automatic Flight recording to be used with it. This is important because using a specified initial conditions set or Auto Fly recording with a particular exercise will place the simulated aircraft in the vicinity of the activated target sites and will provide an additional degree of standardization for the planned target engagement instruction. If used with another set or recording, the occurrence of a particular event would be less predictable, and standardization of training would suffer.

Following development of a scenario which identifies the target events appropriate to be included in the exercise and the contingencies to be used to trigger insertion of each event, the exercise itself must be prepared. This is done interactively with the simulator through controls and displays located at the IS. Using a programmed question and answer format, the instructor will identify the target sites to be activated and the particular target to be positioned at each. He will then select one of the available target events, designate the target with which it is to be associated (if applicable), and specify the event insertion contingencies. The contingencies will be specified in terms of arithmetic operations (equal to, greater than, less than) and logical operators (AND and OR) on parameters such as own-ship line of sight exposure to a target, and events such as own-ship weapons release. In specifying these contingencies, the instructor will select one or more parameters from among a set of programmed parameters, specify the logical operator involved (if more than one contingency parameter is seleced), and "assemble" the contingencies desired to trigger each target event. Up to a minimum of five different parameters can be involved in triggering each event, although one or two will be sufficient in most instances. These exercise assembly activites will be repeated for each target event to be included in the exercise.

APPENDIX E
SFTS SOFTWARE MODULE
COMMONALITY ANALYSIS MATRIX

LEGEND

R = Related
S = Functionally Similar
- = Little or no correspondence
? = Unknown

2B40 AH-64 CMS		2B31 CH-47	2B33 AH-1	2B38 UH-60
G700	MAIN GEAR BRAKES AND TAIL WHEEL MODULE	R	-	S
G998	ROTOR BRAKE MODULE	?	?	S
G850	ANTI-ICE SYSTEM MODULE	S	S	S
G800	FIRE DETECTION AND EXTINGUISHING SYSTEM MODULE	S	S	S
G600	APU START LOGIC MODULE	S	-	S
G601	APU RUN LOGIC MODULE	S	-	S
G602	APU RPM RUN LOGIC MODULE	S	-	S
G930	MAIN TRANSMISSION MODULE	R	S	S
G910	FUEL SYSTEM MODULE	S	S	S
G550	HYDRAULIC MODULE	S	S	S
G350	PRESSURIZED AIR SYSTEM (PAS) MODULE	S	S	R
G351	ENVIRONMENTAL CONTROL SYSTEM (ECS) MODULE	?	?	S
G999	AIR DATA SENSOR SUBSYSTEM (ADSS) MODULE	-	-	-
F131	PRIMARY FLIGHT CONTROL SYSTEM (PFCS) MODULE	S	S	
F141	DASE CONTROL LOGIC MODULE	R	R	S
F142	DASE MODE LOGIC MODULE	R	R	S
F148	EASY-OFF/EASY-ON CHANNEL GAIN PROCESS MODULE	R	R	S
F149	SCAS MALFUNCTION PROCESS MODULE	R	R	S
F151	STABILATOR CONTROL SYSTEM MODULE	-	-	S
E500	ENGINE THERMODYNAMICS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
E510	ENGINE INITIALIZATION MODULE	S	S	S
E530	ELECTRONIC CONTROL UNIT (ECU) MODULE	S	S	S
E540	HYDROMECHANICAL CONTROL UNIT (HCU) MODULE	S	S	S
E550	ENGINE START MODULE	S	S	S
E560	ENGINE OIL MODULE	S	S	S
E570	THROTTLE DRIVES MODULE	S	S	S
E580	ENGINE LFI CALLS MODULE	S	S	S
F510	ENVIRONMENT MODULE	S	S	S
F560	ROTOR DYNAMICS MODULE	S	S	S
F500	EQUATIONS OF MOTION MODULE	S	S	S
F550	WEIGHT AND BALANCE MODULE	S	S	S
F520	GROUND CONTACT DYNAMICS MODULE	S	S	R
F590	CRASH MODULE	S	S	S
F585	FLIGHT TRIMMER MODULE	S	S	S
F580	FLIGHT INITIALIZATION MODULE	S	S	S
F920	FLIGHT INSTRUMENTS MODULE	S	S	S
E520	ENGINE INSTRUMENTS MODULE	S	S	S
N560	AUTOMATIC DIRECTION FINDER MODULE	S	-	S
N530	PILOT VHF MODULE	S	S	S
N950	DOPPLER EXECUTIVE MODULE	-	-	-

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
N951	DOPPLER STEERING MODULE	-	-	-
N952	DOPPLER NAVIGATION MODULE	-	-	-
N955	DOPPLER MAGNETIC VARIATION MODULE	-	-	-
N957	DOPPLER TEST MODULE	-	-	-
N958	DOPPLER AUXILIARY OUTPUT MODULE	-	-	-
N953	COMPUTER DISPLAY CONTROL MODULE	-	-	-
N650	RADAR ALTIMETER MODULE	S	S	S
N625	STANDBY ADI AND STANDBY COMPASS MODULE	S	S	S
N907	DDP INITIALIZATION (DDPINI) MODULE	S	S	S
N991	DDP SEARCH SUBROUTINE (NDDP2 AND RESEARCH) MODULE	S	S	S
N998	DDP DISK CALL ROUTINE (DDPDSK) MODULE	S	S	S
N999	NAV RECEIVER SUBROUTINE (NAVRCV) MODULE	S	S	S
N880	ADF MODULE	S	S	S
N881	ADF IDENT MODULE	S	S	S
N600	PRECISION APPROACH RADAR (GCA/PAR) MODULE	S	S	S
P860	NAVADM DDP COMPILER-MAIN MODULE	R	R	S
P878	ANGCON ANGLE CONVERSION TO D-M-S MODULE	R	R	S
P877	ASCINF ASCII (AI) TO INTEGER (N = 6 MAX) MODULE	R	R	S
P888	CALLCD CALL DOCE GENERATOR MODULE	R	R	S
Z525	DATIMW DATE/TIME MODULE	R	R	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P862	FNDERR FIND COMMON CARD ERRORS MODULE	R	R	S
Z526	IDPAK MORSE IDENT PACKER MODULE	R	R	S
P887	INIT INITALIZE STATION BUFFERS MODULE	R	R	S
P881	INITFD INITIALIZE ALL RECORDS NAVFIL MODULE	R	R	S
P873	LATLON LAT/LONG D-M-S ASCII TO REAL MODULE	R	R	S
P882	LIST LIST STATIONS BY DISK ORDER MODULE	R	R	S
P884	LISTA LIST STATIONS BY AREA ORDER MODULE	R	R	S
P885	LISTC LIST STATIONS BY CALL ORDER MODULE	R	R	S
P883	LISTF LIST STATIONS BY FREQUENCY ORDER MODULE	R	R	S
P886	LISTS LIST STATION BY TYPE/AREA/SORT ORDER MODULE	R	R	S
P890	MODNAY ADD/DEL/REV STATION MODULE	R	R	S
P876	OBTERO CONVERT FREQUENCY CHANNEL MODULE	R	R	S
P875	OBTINT ASCII (A1) TO INTEGER (N = 11 MAX) MODULE	R	R	S
P874	OBTREL ASCII (A1) TO REAL MODULE	R	R	S
P864	PRC0 PROCESS CARD 0 MODULE	R	R	S
P865	PRC1 PROCESS CARD 1 MODULE	R	R	S
P866	PRC2 PROCESS CARD 2 MODULE	R	R	S
P867	PRC3 PROCESS CARD 3 MODULE	R	R	S
P868	PRC4 PROCESS CARD 4 MODULE	R	R	S
P869	PRC5 PROCESS CARD 5 MODULE	R	R	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P870	PRC6 PROCESS CARD 6 MODULE	R	R	S
P871	PRC7 PROCESS CARD 7 MODULE	R	R	S
P872	PRC8 PROCESS CARD 8 MODULE	R	R	S
P861	PRCNFC PROCESS NAV FACILITY CARDS MODULE	R	R	S
P889	PRINT PRINT STATION PARAMETERS MODULE	R	R	S
P863	PRTERR PRINT ERRORS OF A CARD MODULE	R	R	S
P879	STACON STATION TYPE CONVERSION (HEX OR ASCII) MODULE	R	R	S
P992	DDPRE DDP PRESELECT BUILDER MODULE	R	R	S
N010	NAV GEOGRAPHY MODULE	S	S	S
N020	AVERAGE LATITUDE MODULE	S	S	S
N021	TERRAIN ELEVATION MODULE	S	S	S
N022	NAV ISOLATE MODULE	S	S	S
N530	PILOT VHF RADIO AUDIO MODULE	S	S	S
N534	CPG VHF RADIO AUDIO MODULE	S	S	S
N540	UHF-AM MODULE	S	S	S
N545	KY-2B SECURE VOICE MODULE	S	S	S
N660	AIRCRAFT IDENTIFICATION SYSTEM MODULE	S	S	S
N645	INSTRUCTIONAL COMMUNICATIONS MODULE	R	S	R
B100	FCC LOGIC MODULE	-	-	-
B300	DATA ENTRY KEYBOARD MODULE	-	-	-

SFTS SOFTWARE MODULE
COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND
R = Related
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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
R100	TADS CONTROL AND INTERFACE MODULE	-	-	-
R200	PNVS MODULE	-	-	-
R400	IHADSS CONTROL AND INTERFACE MODULE	-	-	-
R450	IHADSS MISSING-MAN LINE-OF-SIGHT MODULE	-	-	-
R500	VIDEO SWITCHING CONTROL AND INTERFACE CONTROL MODULE	-	-	-
R550	VDU DISPLAY MODULE	-	-	-
R560	VDU TURN/SLIP INDICATOR MODULE	-	-	-
R600	SYMBOL GENERATOR POWER AND INTENSITY CONTROL MODULE	-	-	-
A200	GUN TURRET AND ELECTRONICS MODULE	-	S	-
A500	STORES MANAGEMENT/JETTISON MODULE	-	S	-
J700	PSP RESULT DISTRIBUTION MODULE	-	-	-
J710	PSP PRIORITY SELECTION MODULE	-	-	-
J720	PSP REQUEST SELECTION MODULE	-	-	-
J720	PSP OUTPUT BUFFER MODULE	-	-	-
J100	TARGET CONTROL ACTIVATION MODULE	-	-	-
J110	TARGET CONTROL LOS AND OCCULTING MODULE	-	-	-
J120	TARGET CONTROL ACTIVITY MODULE	-	S	-
C100	IR JAMMING MODULE	?	-	-
C300	CHAFF DISPENSER POWER MODULE	?	?	-
C310	CHAFF DISPENSING MODULE	?	?	-
H100	AIRCRAFT OPERATION SOUNDS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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2B40 AH-64 CMS		2B31 CH-47	2B33 AH-1	2B38 UH-60
H200	TACTICS SOUNDS MODULE	S	S	S
U400	KEYBOARD SAMPLER INHIBIT PROCESS MODULE	-	S	S
U401	ENTER PROCESS MODULE	S	S	S
U402	TAB PROCESS MODULE	S	S	S
U403	MINUS PROCESS MODULE	S	S	S
U404	DECIMAL PROCESS MODULE	S	S	S
U405	CLEAR PROCESS MODULE	S	S	S
U406	BACKSPACE PROCESS MODULE	S	S	S
U407	PAGE FORWARD/BACK/RECALL PROCESS MODULE	S	S	S
U408	DISPLAY PROCESS MODULE	S	S	S
U409	DIGITS PROCESS MODULE	S	S	S
U410	PREP EDIT AREA PROCESS MODULE	S	S	S
U450	PAGE DISPLAY PROCESS MODULE	S	S	S
U452	INSTRUCTIONAL FEATURE SETS MODULE	S	S	S
U459	INTEGRATED DATA TRANSFER PROCESS MODULE	S	S	S
U451	SET LOAD REQUEST PROCESS MODULE	S	S	S
U453	ITEM DISPLAY PROCESS MODULE	S	S	S
U454	ITEM ENTRY PROCESS MODULE	S	S	S
U458	ACTIVITY MONITOR DRIVER PROCESS MODULE	S	S	S
U456	PAGE ACTIVATE MODULE	S	S	S

SFTS SOFTWARE MODULE
COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
U457	SANDERS START-UP MODULE	S	S	S
U455	DYNAMIC DATA COLLECTOR MODULE	S	S	S
U458	ACTIVITY MONITOR DRIVER MODULE	S	S	S
U460	UTM CONVERTER MODULE	S	S	S
U580	HARDCOPY PREPARATION PROCESS MODULE	R	R	R
U581	REQUEST MODULE	R	R	R
U582	QUEUE MODULE	R	R	R
U583	DISCSAVE MODULE	R	R	R
U584	DISCREAD MODULE	R	R	R
U585	HCWRITE MODULE	R	R	R
U586	HCINIT MODULE	R	R	R
U587	HCIODONE MODULE	R	R	R
U588	HCCOMPLT MODULE	R	R	R
U589	ERROR MODULE	R	R	R
U590	HARDCOPY TIMER SERVICE PROCESS MODULE	R	R	R
U550	PLOT CONTROL MODULE	S	S	S
U540	INIT FLAGS AND POINTERS MODULE	S	S	S
U530	CROSS COUNTRY OR TIGA MODULE	S	S	S
U531	TARGET SITES MODULE	-	S	-
U532	SITE PATHWAY DETAIL MODULE	-	S	-

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
U533	B.P./B.P.T.S MODULE	S	S	S
U534	ALT/ASP PLOT MODULE	S	S	S
U535	GCA PLOT MODULE	S	S	S
U551	VERIFY SUBPROCESS FLAGS MODULE	S	S	S
U557	NAV/COM FACILITIES PLOT MODULE	S	S	S
U558	TARGET SITE PLOT MODULE	-	S	-
U568	PATHWAY DETAIL MODULE	-	S	-
U554	AIRCRAFT TRACK HISTORY MODULE	S	S	S
U556	AIRCRAFT TRACK BUILD MODULE	S	S	S
U560	TERRAIN FEATURES MODULE	-	-	-
U559	ACTIVE TARGET PLOT MODULE	-	S	-
U564	ALTITUDE/AIRSPEED PLOT MODULE	S	S	S
U566	GCA PLOT MODULE	S	S	S
U562	UTM BATTLE POSITIONS MODULE	-	-	-
U570	DOPPLER COMPUTER FACSIMILE PAGE MODULE	-	-	-
U575	CLIPPING ROUTINE MODULE	S	S	S
U576	CLIPPING ROUTINE ENDPOINT CODE MODULE	S	S	S
T210	SCANNER MODULE	S	S	S
T240	SYNTAX MODULE	S	S	S
T230	CODE GENERATOR MODULE	S	S	S

SFTS SOFTWARE MODULE
COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
U520	MODE CONTROL MODULE	-	S	-
M500	MALFUNCTION NUMBER MODULE	S	S	S
M510	MALFUNCTION INDEX AND VALUE MODULE	S	S	S
M515	INSERT/DELETE MALFUNCTIONS MODULE	S	S	S
U600	IC RUN REQ. PROCESS MODULE	S	S	S
U601	CHECK VISUAL REQUEST MODULE	S	S	S
U602	PERFORM IC MODULE	S	S	S
U603	RESTART IC PROCESS MODULE	S	S	S
U604	OVERRIDE VISUAL MODE PROCESS MODULE	S	S	S
U605	RUN DISPLAY IC PROCESS MODULE	S	S	S
U606	MASTER DATA RESET PROCESS MODULE	S	S	S
U607	MASTER DATA RESET PROCESS MODULE	S	S	S
U608	MODE MASTER DATA RESET PROCESS MODULE	S	S	S
U609	IC LOAD PROCESS MODULE	S	S	S
U610	SAVE DISPLAY PROCESS MODULE	S	S	S
U611	EXTRACT CURRENT STATE PROCESS MODULE	S	S	S
U500	CPG SENSE DI PROCESS MODULE	S	S	S
U502	PLT SENSE DI PROCESS MODULE	S	S	S
U504	CPG UPDATING PROCESS MODULE	S	S	S
U506	PLT UPDATING PROCESS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
U508	TIMER PROCESS MODULE	S	S	S
U509	INITIALIZATION PROCESS MODULE	S	S	S
U519	PARAMETER FREEZE PROCESS MODULE	S	S	S
M100	AMI SET NUMBER FOR PREVIEW PROCESS MODULE	-	-	-
M130	HALT ACTIVE AMI SET PROCESS	-	-	-
T500	PROBLEM FORMULATE CONTROL MODULE	-	-	-
T501	AMI TAB KEY PROCESSING MODULE	-	-	-
T505	TEE TAB KEY PROCESSING EVENTS MODULE	-	-	-
T506	TEE TAB KEY PROCESSING (TARGETS) MODULE	-	-	-
T502	AMI ENTRY COMPLETE KEY PROCESSING MODULE	-	-	-
T503	AMI ENTRY COMPLETE DISK I/O MODULE	-	-	-
T504	AMI ERROR CHECK MODULE	-	-	-
T502	AMI ENTRY COMPLETE PROCESSING MODULE	-	-	-
T507	TEE ENTRY COMPLETE KEY PROCESSING MODULE	-	-	-
T508	TEE ENTRY COMPLETE DISK I/O MODULE	-	-	-
T509	TEE ENTRY COMPLETE-PROCESS COMPLETED LINE MODULE	-	-	-
T512	MISCELLANEOUS KEYS PROCESSING MODULE	-	-	-
T511	TEE TARGET ERROR CHECK MODULE	-	-	-
T510	TEE EVENT ERROR CHECK MODULE	-	-	-
T513	AMI ENTRY COMPLETE-PROCESS COMPLETED LINE MODULE	-	-	-

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Y500	PREVIEW TEE SET MODULE	-	-	-
Y501	AMI/TEE DIRECTORY MODULE	-	-	-
Y510	ACTIVATE TEE SET NUMBER MODULE	-	-	-
Y511	FILL TARGET DATA ARRAYS MODULE	-	-	-
Y520	MONITOR TEE EVENTS MODULE	-	-	-
Y521	CONSTRUCT FORTRAN CONDITIONS MODULE	-	-	-
Y522	DETERMINE CURRENT VALUE OF MONITORED PARAMETER MODULE	-	-	-
Y530	MANUAL TARGET CONTROL MODULE	S	S	-
Y531	ERROR CHECK ON MANUAL TARGET DATA MODULE	S	S	-
Y540	TARGET EVALUATION FEATURE MODULE	S	S	-
Y541	TARGET EVALUATION EDIT PARAMETER MODULE	S	S	-
Y550	IMPACT INDICATORS/INITIALIZATION MODULE	S	S	-
U521	GCA MONITOR MODULE	S	S	S
U522	GCA CONTROL MODULE	S	S	S
U523	CALCULATIONS MODULE	S	S	S
U524	FINAL MESSAGES MODULE	S	S	S
U525	GLIDEPATH MESSAGES MODULE	S	S	S
U526	COURSE MESSAGES MODULE	S	S	S
X500	REQUEST PROCESSOR MODULE	-	-	-

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
X501	CPU 1/4 STORE PROCESSOR MODULE	-	-	-
X502	CPU 2/5 STORE PROCESSOR MODULE	-	-	-
X503	CPU 3/6 STORE PROCESSOR MODULE	-	-	-
X504	FCC STORE PROCESSOR MODULE	-	-	-
X505	DISK OUTPUT PROCESSOR MODULE	-	-	-
X506	DISK INPUT PROCESSOR MODULE	-	-	-
X507	FCC RESET PROCESSOR MODULE	-	-	-
X508	CPU 1/4 RESET PROCESSOR MODULE	-	-	-
X590	CPU 2/5 RESET PROCESSOR MODULE	-	-	-
X510	CPU 3/6 RESET PROCESSOR MODULE	-	-	-
U530	FREEZE MONITOR MODULE	S	S	S
U531	DISCREPANCY CHECKS PROCESSOR MODULE	-	-	-
Q105	LOAD INITIALIZATION MODULE	S	S	S
Q106	OPERATOR DIALOG MODULE	S	S	S
Q100	REAL-TIME EXEC MODULE	S	S	S
Q102	FRAME TIMER MODULE	S	S	S
Q103	MODULE TIMER MODULE	S	S	S
Q101	ERROR/TRAP HANDLER MODULE	S	S	S
Q104	ERROR MESSAGE SERVICE MODULE	S	S	S
Q120	I/O SERVICE MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Q700	LINKAGE DRIVER MODULE	S	S	S
Q767	DVS HANDLER MODULE	S	-	-
Q713	GRAPHIC 7 DRIVER MODULE	S	S	S
Q800	PIC/CTE HANDLER MODULE	?	?	?
Q810	FCC HANDLER MODULE	-	-	-
Q912	DEBUG TASK INITIALIZATION (MASTER) MODULE	S	S	S
Q960	DEBUG CRT INITIALIZATION (MASTER) MODULE	S	S	S
Q970	QSYINT INITIALIZATION ROUTINE FOR Q943 (QSYMLK) MODULE	S	S	S
Q950	RTD DUMP TO LP MODULE	S	S	S
Q951	RECORDING ROUTINE MODULE	S	S	S
Q952	RTD-RTP OVERLAY CONTROL MODULE	S	S	S
Q953	QRTPCI PRINT COMMAND INTERPRETER SUBROUTINE (Q900 OVERLAY OF Q952) MODULE	S	S	S
Q961	CRT PAGE DATA OUTPUT CONTROL (MASTER) MODULE	S	S	S
Q962	CRT PAGE OUTPUT CONTROL (MASTER) MODULE	S	S	S
Q965	QPAGE RETRIEVE AND DISPLAY CRT PAGE (MASTER) MODULE	S	S	S
Q904	QCPP CRT PAGE COMMANDS (MASTER) MODULE	S	S	S
Q963	DCRTF01 DEBUG CRT DRIVER (MASTER) MODULE	S	S	S
Q901	QTRACE DUMP COMMAND ANALYSIS (MASTER) MODULE	S	S	S
Q905	QTIMING ANALYZE TIMING COMMANDS (MASTER) MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
S = Functionally Similar
- = Little or no correspondence
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Q914	QMDTIM MODULE TIMING (SLAVE) MODULE	S	S	S
Q933	DUMP DATA GATHERING MODULE (SLAVE)	S	S	S
Q934	DUMP OUTPUT CONTROL (MASTER) MODULE	S	S	S
Q902	QBREAK ANALYZE BREAKPOINT COMMANDS (MASTER) MODULE	S	S	S
Q931	BREAKPOINT DATA GATHERING MODULE	S	S	S
Q932	BREAKPOINT OUTPUT CONTROL (MASTER) MODULE	S	S	S
Q990	Q906OV OVERLAY CONTROL MODULE FOR Q906	S	S	S
Q991	Q902OV OVERLAY CONTROL MODULE FOR Q902	S	S	S
Q992	Q901OV OVERLAY CONTROL MODULE FOR Q901	S	S	S
Q993	Q904OV OVERLAY CONTROL MODULE FOR Q904	S	S	S
Q994	Q905OV OVERLAY CONTROL MODULE FOR Q905	S	S	S
Q964	QCRTRV POWER-FAIL/RESTORE MASTER CPU MODULE	S	S	S
Q900	COMMAND INTERPRETER (MASTER) MODULE	S	S	S
Q903	QLANDE LOOK AND ENTER (MASTER) MODULE	S	S	S
Q906	QSIM ANALYZE SIMULATION CONTROL COMMANDS (MASTER) MODULE	S	S	S
Q915	QGTVAR SATISFY VARIABLE ADDRESSES AND RELATIONAL CONDITION (SLAVE) MODULE	S	S	S
Q913	QCONV CONTROL INPUT AND OUTPUT CONVERSIONS (MASTER) MODULE	S	S	S
Q911	QCKCND CHECK RELATIONAL CONDITION (SLAVE) MODULE	S	S	S
Q910	QFMTST ANALYZE FORMAT SPECIFICATION (SLAVE) MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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2B40 AH-64 CMS		2B31 CH-47	2B33 AH-1	2B38 UH-60
Q920	COMMAND DISPATCHER (MASTER) MODULE	S	S	S
Q921	COMMAND PROCESSOR (SLAVE) MODULE	S	S	S
Q922	QRMOVE DEBUG FUNCTION REMOVAL (SLAVE) MODULE	S	S	S
Q940	QLINE BUILD LINE FOR CRT FROM SYMBOL DICTIONARY (MASTER) MODULE	S	S	S
Q941	QFCBS DEBUG CRT OUTPUT QUEUER (MASTER) MODULE	S	S	S
Q942	QCRTDR CONTROL OUTPUT OR PROMPT CHARACTERS MODULE	S	S	S
Q944	QFTSTR FETCH/STORE ANY LOCATION (SLAVE) MODULE	S	S	S
Q943	QSYMLK REAL-TIME INTERFACE TO SYMBOL DICTIONARY (MASTER) MODULE	S	S	S
Q954	QCTCMD BUILD CRT COMMANDS (MASTER) MODULE	S	S	S
Q962	QCRTRS CRT RESTART MODULE	S	S	S
Q930	DUMMY TEST MODULE	?	?	?
P612	PRETRE MODULE	S	S	S
P613	TREBLD MODULE	S	S	S
P654	DRDOUT MODULE	S	S	S
P650	AIDIWI MODULE	S	S	S
P614	INTRE MODULE	S	S	S
P615	PDINIT MODULE	S	S	S
P616	PDDATA MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P617	OVERLAY CONTROL MONITOR MODULE	S	S	S
P618	PMLINK MODULE	S	S	S
P619	MASKIT MODULE	S	S	S
P620	PMNUAL MODULE	S	S	S
P621	PMFAST MODULE	S	S	S
P622	PSCDSP MODULE	S	S	S
P623	CRTOT MODULE	S	S	S
P624	KEYIN MODULE	S	S	S
P625	PCRTCL MODULE	S	S	S
P626	PMMENU MODULE	S	S	S
P627	PDREDM MODULE	S	S	S
P628	PDREDA MODULE	S	S	S
P629	DCE11 MODULE	S	S	S
P630	DCE12 MODULE	S	S	S
P631	DCEOT MODULE	S	S	S
P632	PBUILD MODULE	S	S	S
P633	REFDES MODULE	S	S	S
P634	PDIUPK MODULE	S	S	S
P635	DONE1 MODULE	S	S	S
P636	TOGGLE SPECIAL SYMBOLS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P637	TOGGLE SPECIAL SYMBOLS MODULE	S	S	S
P641	G7TST GRAPHIC 7 TEST MODULE	S	S	S
P642	G710 MODULE	S	S	S
P643	DSTST D/S TEST MODULE	S	S	S
P646	SDTST S/D TEST MODULE	S	S	S
P649	PRAMPC MODULE	S	S	S
P655	PRAMP MODULE	S	S	S
P647	DVS AUDIO TEST MODULE	S	S	S
P680	IKBIN MODULE	S	S	S
P682	CPU 4 ROUTINE DEV I/O MODULE	S	S	S
P685	CPU 4 OVERLAY FOR MFD TEST MODULE	S	S	S
P690	RUN TIME LIBRARY LINKAGE MODULE	S	S	S
P691	DUMMY RTL FOR SUBROUTINES MODULE	S	S	S
P774	ICSF01 MODULE	S	S	S
P750	CLLTB MAIN ROUTINE MODULE	S	S	S
P751	CLLTA LINKAGE CONTROL MODULE	S	S	S
P752	INIT MODULE	S	S	S
P753	CLEAN MODULE	S	S	S
P754	DPT MODULE	S	S	S
P755	FPC MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND
R = Related
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2B40 AH-64 CMS		2B31 CH-47	2B33 AH-1	2B38 UH-60
P756	MEM MODULE	S	S	S
P757	PDL MODULE	S	S	S
P758	SYNTAX MODULE	S	S	S
P759	UNPACK MODULE	S	S	S
P760	SEARCH MODULE	S	S	S
P761	DEL MODULE	S	S	S
P762	LEXAN MODULE	S	S	S
P763	DMA MODULE	S	S	S
P764	INPUT MODULE	S	S	S
P765	OUTPUT MODULE	S	S	S
P767	SCT MODULE	S	S	S
P768	ICSERR MODULE	S	S	S
P769	NMERR MODULE	S	S	S
P770	TMERR MODULE	S	S	S
P771	CONVRT MODULE	S	S	S
P772	CLLTSUB MODULE	S	S	S
Q155	US15F01 MODULE	S	S	S
Q712	U15PF01A MODULE	S	S	S
Q700	SCE HANDLER MODULE	S	S	S
P101	CONF MODULE	?	?	?

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P100	PRESOR MODULE	?	?	?
P540	CONFIG MODULE	?	?	?
P127	VOLDAT MODULE	?	?	?
P724	GLIBLOG MODULE	?	?	?
P901	UNPKAG MODULE	?	?	?
P902	UNPKPR MODULE	?	?	?
P777	DISK COMPARE PREPROCESSOR MODULE	?	?	?
P778	PROD MODULE	?	?	?
P891	DATETIME MODULE	?	?	?
P892	LIBLOG MODULE	?	?	?
P855	SYMIO MODULE	?	?	?
P000	UDPATE/CONFCK MODULE	S	S	S
P538	UPSORT MODULE	S	S	S
P051	SDINIT SYMBOL DICTIONARY INITIALIZATION MODULE	S	S	S
P053	XREF CROSS REFERENCE MODULE	S	S	S
P054	SDUP SYMBOL DICTIONARY UPDATE MODULE	S	S	S
P055	MAP SYMBOLIC MEMORY MAP MODULE	S	S	S
P059	PEQIV EQUIVALENCE PROCESSOR MODULE	S	S	S
P058	DELETE SET RESP COUNT FOR DELETED SYMBOLS MODULE	S	S	S
P057	PBASE SET UP FILES FOR REBUILD MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P049	EQUV FIND PARENTS OF EXISTING EQUIVALENCES MODULE	S	S	S
P047	SDRT WRITE SD DEFINITIONS TO SDINPT MODULE	S	S	S
P048	FLINT RESET COUNTERS IN INPUT FILES FOR REBUILD MODULE	S	S	S
P052	SORT ALPHABETIC SORT MODULE	S	S	S
P071	SCAN MODULE	S	S	S
P090	TSKGEN MAIN MODULE	S	S	S
P091	MODULE CONTROL TABLE GENERATION MODULE	S	S	S
P092	FRAME MASK CALCULATION MODULE	S	S	S
P060	CTFR DRIVER OF CRT FORMATTER SYSTEM MODULE	S	S	S
P061	CTRI INITIALIZE CRT PAGES FILE MODULE	S	S	S
P063	CRTERR PRINT ERROR MESSAGES MODULE	S	S	S
P064	CRTOPR CRT PRINT MODULE	S	S	S
P065	CRTHED CRT HEADER MODULE	S	S	S
P066	CRTPIC CRT INTERPRET PICTURE RECORDS MODULE	S	S	S
P067	CRTSYM CRT SYMBOL DATA MODULE	S	S	S
P068	PSXCHT COMPARE ARGUMENT TO LITERAL MODULE	S	S	S
P120	PAKARD PACK RECORDS INTO DISK MODULE	S	S	S
P533	COMOUT SUBROUTINE MODULE	S	S	S
P880	ZCOMP LFT COMPILER MODULE	S	S	S
Z500	ZARGS ARGUMENT SEARCH PROCESS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z501	ZLFI1 MODULE	S	S	S
Z502	ZLFI2 MODULE	S	S	S
Z503	ZLFI3 MODULE	S	S	S
Z506	ZLFISF MODULE	S	S	S
Z567	ZARGS MODULE	S	S	S
Z568	WCS LFI ARGUMENT TO SEARCH ROUTINE MODULE	S	S	S
Z563	LFI ONE VARIABLE (INTF) MODULE	S	S	S
Z564	WCS ONE VARIABLE LFI ROUTINE MODULE	S	S	S
Z565	LFI TWO VARIABLE (INFT) MODULE	S	S	S
Z566	WCS TWO VARIABLE LFI ROUTINE MODULE	S	S	S
Z554	WCS SCALE FACTOR TABLE FOR UFI MODULE	S	S	S
Z550	WCS FLOAT TO FIX ROUTINE MODULE	S	S	S
Z552	WCS FIX TO FLOAT ROUTINE MODULE	S	S	S
P700	PTRGEN MODULE	?	?	S
0549	TREERP TREE REPORT PROGRAM MODULE	-	-	?
0550	ALPHA ALPHABETICAL LISTING MODULE	-	-	?
P609	SORT-MERGE MODULE	S	S	S
Z529	AEPC ANGLE INPUT IN DEGREES MODULE	S	S	S
Z012	ALIM MODULE	S	S	S
Z156	ALIMAS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z004	ARCTAN MODULE	S	S	S
Z123	ASCFL MODULE	S	S	S
Z169	ASCFLC MODULE	S	S	S
Z129	ASCHEX MODULE	S	S	S
Z127	ASCHMS MODULE	S	S	S
Z171	ASCHXC MODULE	S	S	S
Z132	ASCIN MODULE	S	S	S
Z151	ASCINC MODULE	S	S	S
Z125	ASCLAT MODULE	S	S	S
Z173	ASCLGC MODULE	S	S	S
Z126	ASCLON MODULE	S	S	S
Z128	ASCOCT MODULE	S	S	S
Z003	ATAN2 MODULE	S	S	S
Z124	BCDFL MODULE	S	S	S
Z131	BCDIN MODULE	S	S	S
Z133	BCDINT MODULE	S	S	S
Z517	BITFR MODULE	S	S	S
Z518	BITFRH MODULE	S	S	S
Z514	BITS MODULE	S	S	S
Z515	BITTS MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z137	BRTIME MODULE	S	S	S
Z139	BTIME MODULE	S	S	S
Z190	CHANGE MODULE	S	S	S
Z101	CHAR MODULE	S	S	S
Z053	CONFIG MODULE	S	S	S
Z543	CONFRT MODULE	S	S	S
Z054	CONFWR MODULE	S	S	S
Z113	CONTRB MODULE	S	S	S
Z186	CONTRD MODULE	S	S	S
Z540	CONTRL MODULE	S	S	S
Z008	COS MODULE	S	S	S
Z010	COSDG MODULE	S	S	S
Z015	DASFL MODULE	S	S	S
Z175	DASFLC MODULE	S	S	S
Z525	DATIMW MODULE	S	S	S
Z119	DECODE MODULE	S	S	S
Z110	DEFCHK MODULE	S	S	S
Z020	DEFIN MODULE	S	S	S
Z112	DEFSPL MODULE	S	S	S
Z146	DEL MODULE	S	S	S
Z144	DELETE MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z120	DEVTAB MODULE	S	S	S
Z014	DFLAS MODULE	S	S	S
Z118	ENCODE MODULE	S	S	S
Z181	ENTOVL MODULE	S	S	S
Z138	ERTIME MODULE	S	S	S
Z021	ESRD MODULE	S	S	S
Z140	ETIME MODULE	S	S	S
Z184	FETSTR MODULE	S	S	S
Z104	FINR MODULE	S	S	S
Z046	FLBCD MODULE	S	S	S
Z527	FLOAS MODULE	S	S	S
Z511	FLOASC MODULE	S	S	S
Z116	GATHER MODULE	S	S	S
Z535	GAUSS MODULE	S	S	S
Z096	GENEVA MODULE	S	S	S
Z528	GRAYCD MODULE	S	S	S
Z191	HEAD MODULE	S	S	S
Z017	HEADER MODULE	S	S	S
Z105	HEADR MODULE	S	S	S
Z080	HEXASC MODULE	S	S	S
Z052	HMSASC MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z159	ICLR MODULE	S	S	S
Z154	IDINT8 MODULE	S	S	S
Z526	IDPACK MODULE	S	S	S
Z160	IEXT MODULE	S	S	S
Z180	INITOV MODULE	S	S	S
Z161	INSERT MODULE	S	S	S
Z040	INTAS MODULE	S	S	S
Z510	INTASC MODULE	S	S	S
Z042	INTBCD MODULE	S	S	S
Z163	IPAC MODULE	S	S	S
Z164	IROTAT MODULE	S	S	S
Z165	ISET MODULE	S	S	S
Z134	ISHFTL MODULE	S	S	S
Z166	ISHIFT MODULE	S	S	S
Z167	IXOR MODULE	S	S	S
Z047	LATASC MODULE	S	S	S
Z155	LEOR MODULE	S	S	S
Z098	LINK MODULE	S	S	S
Z182	LODOVL MODULE	S	S	S
Z049	LONASC MODULE	S	S	S
Z026	LSCAN MODULE	S	S	S

SFTS SOFTWARE MODULE
COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z060	MATMAT MODULE	S	S	S
Z061	MATMTP MODULE	S	S	S
Z058	MATV MODULE	S	S	S
Z086	MODCTL MODULE	S	S	S
Z148	MTIME MODULE	S	S	S
Z062	MTPMAT MODULE	S	S	S
Z063	MTPMTP MODULE	S	S	S
Z059	MTPV MODULE	S	S	S
Z077	OCTASC MODULE	S	S	S
Z534	PACKB MODULE	S	S	S
Z533	PACKM MODULE	S	S	S
Z532	PACKN MODULE	S	S	S
Z136	PDATE MODULE	S	S	S
Z142	PIOS MODULE	S	S	S
Z188	PUTOVL MODULE	S	S	S
Z183	QCLKVL MODULE	S	S	S
Z025	QSCAN MODULE	S	S	S
Z141	QSTADR MODULE	S	S	S
Z513	RANDOM MODULE	S	S	S
Z541	RDRWTR MODULE	S	S	S
Z114	READER MODULE	S	S	S

SETS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

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2B40 AH-64 CMS		2B31 CH-47	2B33 AH-1	2B38 UH-60
Z117	SCATER MODULE	S	S	S
Z007	SIN MODULE	S	S	S
Z005	SINCOD MODULE	S	S	S
Z006	SINCOR MODULE	S	S	S
Z009	SINDG MODULE	S	S	S
Z018	SORT MODULE	S	S	S
Z177	SORTC MODULE	S	S	S
Z000	SQRT MODULE	S	S	S
Z055	SYMLOK MODULE	S	S	S
Z029	SYMOUT MODULE	S	S	S
Z087	SYMWRT MODULE	S	S	S
Z530	UNPAKN MODULE	S	S	S
Z531	UNPKNB MODULE	S	S	S
Z001	VMAG2 MODULE	S	S	S
Z002	VMAG3 MODULE	S	S	S
Z064	VPROD MODULE	S	S	S
Z115	WRITER MODULE	S	S	S
Z189	XNGNAM MODULE	S	S	S
Z520	ZAOLIM MODULE	S	S	S
Z130	ZCBBFR MODULE	S	S	S
Z108	ZCKFLN MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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2B40 AH-64 CMS		2B31 CH-47	2B33 AH-1	2B38 UH-60
Z121	ZDFDTW MODULE	S	S	S
Z107	ZEDDTW MODULE	S	S	S
Z542	ZSCALM MODULE	S	S	S
0513	CONCREAT MODULE	S	S	S
0514	CONUPDAT MODULE	S	S	S
0500	FORM MODULE	S	S	S
0501	CONADD MODULE	S	S	S
0503	NRLWRT MODULE	S	S	S
0502	COMPAR MODULE	S	S	S
0517	TCOWEED MODULE	S	S	S
0518	TJRCDUMP MODULE	S	S	S
0501	MAIN MODULE	S	S	S
0504	GETFD MODULE	S	S	S
0505	OUTLIN MODULE	S	S	S
0506	SORT MODULE	S	S	S
0507	STOPTS MODULE	S	S	S
0508	RVORDR MODULE	S	S	S
0509	OUTPUT MODULE	S	S	S
0510	ORDER MODULE	S	S	S
0511	BISRCH MODULE	S	S	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
0512	CLEAR MODULE	S	S	S
0515	CONSYM MODULE	S	S	S
0519	TJRTRINP MODULE	S	S	S
0520	TCOCONSD MODULE	S	S	S
0521	TCOCFIND MODULE	S	S	S
0522	SNWRESCN MODULE	S	S	S
P820	MAIN MODULE	-	-	S
P821	BLDDIS MODULE	-	-	S
P822	BLDDMA MODULE	-	-	S
P823	BLDIOS MODULE	-	-	S
P824	BLDMAP MODULE	-	-	S
P825	BLDPTR MODULE	-	-	S
P826	DECASC MODULE	-	-	S
P827	ERROR MODULE	-	-	S
P828	FILBAS MODULE	-	-	S
P829	FILDSP MODULE	-	-	S
P830	FNDBAS MODULE	-	-	S
P831	FNDSYM MODULE	-	-	S
P832	GETSYM MODULE	-	-	S
P833	HEADNG MODULE	-	-	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P834	OCTASC MODULE	-	-	S
P835	OUTDIS MODULE	-	-	S
P836	OUTIOS MODULE	-	-	S
P837	OUTMAP MODULE	-	-	S
P838	OUTPTR MODULE	-	-	S
P839	PCKWRD MODULE	-	-	S
P840	RDMABK MODULE	-	-	S
P841	RIODM MODULE	-	-	S
P842	RIOS MODULE	-	-	S
P843	RPTRFL MODULE	-	-	S
P844	RSCDSP MODULE	-	-	S
P845	RSCPTR MODULE	-	-	S
P846	RSD MODULE	-	-	S
P847	SCHBAS MODULE	-	-	S
P848	SCHDMA MODULE	-	-	S
P849	SETUP MODULE	-	-	S
P850	UNPACK MODULE	-	-	S
P851	WIODM MODULE	-	-	S
P852	WIOS MODULE	-	-	S
P853	WSCDSP MODULE	-	-	S
P854	WSCPTR MODULE	-	-	S

SFTS SOFTWARE MODULE

COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
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	2B40 AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
P725	WCS LIBRARIAN MODULE	-	-	S
Z556	IGETNM MODULE	-	-	S
P640	WCS FILE TASK MODULE	-	-	S
Q780	QWCSIN MODULE	-	-	S
Q781	QWCSPR MODULE	-	-	S
Z546	WCSI MODULE	-	-	S
Z548	ARCTAN MODULE	-	-	S
Z550	FXR MODULE	-	-	S
Z552	FLR MODULE	-	-	S
Z554	ZLFISF MODULE	-	-	S
Z560	SINCOS MODULE	-	-	S
Z562	AEPC MODULE	-	-	S
Z564	LFI1 MODULE	-	-	S
Z566	LFI2 MODULE	-	-	S
Z568	ARGS MODULE	-	-	S
Z573	ARCSC MODULE	-	-	S
Z577	ALOGS MODULE	-	-	S
Z570	SQROOT MODULE	-	-	S
Z547	ARCTAN MODULE	-	-	S
Z549	SINCOD MODULE	-	-	S

SFTS SOFTWARE MODULE
COMMONALITY ANALYSIS MATRIX (Continued)

LEGEND

R = Related
S = Functionally Similar
- = Little or no correspondence
? = Unknown

2B40	AH-64 CMS	2B31 CH-47	2B33 AH-1	2B38 UH-60
Z551	SINCOR MODULE	-	-	S
Z553	COSDG MODULE	-	-	S
Z555	SINDG MODULE	-	-	S
Z557	COS MODULE	-	-	S
Z559	SIN MODULE	-	-	S
Z561	AEPC MODULE	-	-	S
Z563	ZLFI1 MODULE	-	-	S
Z565	ZLFI2 MODULE	-	-	S
Z567	ZARGS MODULE	-	-	S
Z569	SQRT MODULE	-	-	S
Z571	ASQRT MODULE	-	-	S
Z558	ARCCOS MODULE	-	-	S
Z572	ARCSIN MODULE	-	-	S
Z574	ALOG MODULE	-	-	S
Z576	ALOG10 MODULE	-	-	S
1.1	COMPUTE POWER CONTROL MODULE EQUIVALENT	-	-	-
1.2	COMPUTE LAMP TEST MODULE EQUIVALENT	-	-	-
1.3	COMPUTE GFE POWER CONTROL MODULE EQUIVALENT	-	-	-
1.4	DIAGNOSTICS MODULE EQUIVALENT	-	-	-

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